

Sourcing Decisions in IT Project and Portfolio Management

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Contents

| | |
|---|---------|
| Contents | I-i |
| List of Articles Included in this Dissertation | I-iv |
| I Introduction | I-1 |
| I.1 Objectives and Structure | I-3 |
| I.2 Research Questions | I-4 |
| I.3 References | I-7 |
| II Sourcing Decisions in IT Project and Portfolio Management..... | I.3-1 |
| II.1 Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context | II.1-1 |
| II.1.1 Introduction | II.1-2 |
| II.1.2 Literature Overview | II.1-3 |
| II.1.3 Model | II.1-4 |
| II.1.4 Practical Implications, Limitations and Conclusion..... | II.1-19 |
| II.1.5 References..... | II.1-21 |
| II.2 The Effect of Bargaining Power on Fixed Price IT Outsourcing Decisions ... | II.2-1 |
| II.2.1 Introduction | II.2-2 |
| II.2.2 Literature Overview | II.2-2 |
| II.2.3 Model | II.2-3 |
| II.2.4 Limitations..... | II.2-12 |
| II.2.5 Conclusion and Outlook | II.2-12 |
| II.2.6 References..... | II.2-14 |
| II.3 An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing..... | II.3-1 |
| II.3.1 Introduction | II.3-2 |
| II.3.2 Literature Overview | II.3-3 |
| II.3.3 Model | II.3-5 |

| | | |
|--------|--|---------|
| II.3.4 | Model Evaluation | II.3-6 |
| II.3.5 | On the Importance of Risk Assessment | II.3-11 |
| II.3.6 | Practical Implications, Limitations and Conclusion..... | II.3-12 |
| II.3.7 | References..... | II.3-14 |
| II.3.8 | Appendix I | II.3-18 |
| II.4 | IT-Multisourcingentscheidungen mit Methoden des Portfoliomanagements . | II.4-1 |
| II.4.1 | IT-Sourcing vor dem Hintergrund einer wertorientierten Unternehmensführung..... | II.4-2 |
| II.4.2 | IT-Sourcingentscheidungen im Projektumfeld..... | II.4-3 |
| II.4.3 | Anforderungen an eine Bewertungsmethode für IT- Sourcingentscheidungen..... | II.4-4 |
| II.4.4 | Unterstützung von IT-Sourcingentscheidungen mit Methoden des Portfoliomanagements | II.4-5 |
| II.4.5 | Hilfestellungen für den Einsatz in der Praxis..... | II.4-7 |
| II.4.6 | Anwendungsbeispiel | II.4-8 |
| II.4.7 | Literaturempfehlungen | II.4-11 |
| II.5 | Multivendor Portfolio Strategies in Cloud Computing..... | II.5-1 |
| II.5.1 | Introduction | II.5-2 |
| II.5.2 | Research Objectives | II.5-3 |
| II.5.3 | Literature Overview | II.5-4 |
| II.5.4 | Research Methodology | II.5-5 |
| II.5.5 | Multivendor Sourcing Decision Model | II.5-6 |
| II.5.6 | Model Evaluation based on a Monte Carlo Simulation..... | II.5-11 |
| II.5.7 | Practical Implications, Limitations and Outlook | II.5-13 |
| II.5.8 | References..... | II.5-14 |
| III | Optimization of Estimation Accuracy in Software Development Projects | III-1 |

| | |
|---|--------|
| III.1 Optimization of Estimation Accuracy in Software Development Projects..... | III-1 |
| III.1.1 Introduction | III-2 |
| III.1.2 Research Methodology | III-3 |
| III.1.3 Literature Overview | III-3 |
| III.1.4 Model | III-5 |
| III.1.5 Theoretical and practical contribution, Limitations and Outlook | III-10 |
| III.1.6 References..... | III-12 |
| IV Conclusion and Future Prospects | IV-1 |
| IV.1 Conclusion | IV-1 |
| IV.2 Future Prospects | IV-3 |
| IV.3 References | IV-6 |

Please note: The number of pages, figures, tables and assumptions is distinct for each chapter and paper. References are listed at the end of each chapter.

List of Articles Included in this Dissertation

- A1. Fridgen, G., Mueller, H. V. 2009. „Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context,“ in Proceedings of the 30th International Conference on Information Systems (ICIS) Phoenix, USA.
(VHB-JOURQUAL 2.1: 8.48 points, category A)
- A2. Fridgen, G., Krapp, M., Mueller, H. V. 2010. „The Effect of Bargaining Power on Fixed Price IT Outsourcing Decisions,“ presented at Conference on Information Systems and Technology (CIST) Austin, USA, November 2010; presented at 5th Global Sourcing Workshop (GSW) Courchevel, France, March 2011.
- A3. Fridgen, G., Mueller, H. V. 2011. „An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing,“ in Proceedings of the 32nd International Conference on Information Systems (ICIS) Shanghai, China.
(VHB-JOURQUAL 2.1: 8.48 points, category A)
- A4. Mueller, H. 2013. „IT-Multisourcingentscheidungen mit Methoden des Portfoliomanagements,“ accepted in HMD - Praxis der Wirtschaftsinformatik
(VHB-JOURQUAL 2.1: 5.16 points, category D)
- A5. Koenig, C., Mette, P., Mueller, H. V. 2012. „Multivendor Portfolio Strategies in Cloud Computing,“ in Proceedings of the 21st European Conference on Information Systems (ECIS) Utrecht, Netherlands.
(VHB-JOURQUAL 2.1: 7.37 points, category B)
- A6. Mueller, H. V. 2013. „Optimization of Estimation Accuracy in Software Development Projects,“ submitted to Business and Information Systems Engineering
(VHB-JOURQUAL 2.1: 7,29 points, category B)

I Introduction

During the years of the economic and financial crisis in 2007-2009, spending on information technology (IT) stagnated and even declined. However, already shortly after the turmoil, the dust had settled and investments in IT reached previous growth rates (Gartner 2011). A reason for this quick recovery may be that IT is an essential driver of today's global economy. Maizlish and Handler (2005) emphasize this point as they state that IT fills in the role of the central nervous system for almost every organization. As being the key element of many business models and processes, management of IT also evolved to be one of the major challenges companies are facing. In many cases the value creation potential of IT is not fully exploited. Jeffrey and Leliveld (2004) state, that 'the reason most organizations struggle to demonstrate business gains from information-technology investments is that their IT portfolio management (ITPM) is inadequate.' Therefore, it is of great importance for companies to improve their ITPM models and techniques.

According to Kaplan (2005) IT portfolio management is a 'method for governing IT investments across the organization, and managing them for value.' This is in line with the statements of the IT Governance Institute (2011) which entail that 'value creation of IT investments is one of the most important dimensions of IT's contribution to the business'. However, a large proportion of today's companies have no precisely defined method for evaluating IT. Most companies consider cost of IT investments only, regardless of strategic value and potential benefits. Risk is oftentimes also considered only rudimentary. The resulting misallocation of resources leads to a waste of 20% of IT budgets which, according to the IT Governance Institute (2008), is an annual global value destruction of 600 billion U.S. dollars.

Recent studies show that especially the number and complexity of large IT projects is growing (Flyvbjerg und Budzier 2011). The complexity is intensified by dependencies within one or between different projects and processes and is boosted even further by their growing number. Additionally, the financial pressure due to an increasingly challenging business environment is forcing companies to exploit cost reduction potentials. Therefore, firms rely on different forms of sourcing for services necessary to support their business processes (Dibbern et al. 2004).

The IT Governance Institute states in its Global Status Report (2011) that 'initiatives implemented to respond to the economic downturn by current sourcing situation' are 'optimisation of the project portfolio and the implementation of stricter investment evaluation measures'. Outsourcing activities of the IT department to external service providers are not a new phenomenon and have been discussed scientifically since the 1960s. The first large IT outsourcing megadeal by Eastman Kodak 1989 is regarded as the impetus for the continuing trend. As the IT Governance Institute (2011) states, 'Outsourcing can create significant benefits, with the proper governance focus. Enterprises using outsourcing are more likely to have a pro-active role of IT and a better perception of IT service levels and less likely to experience issues related to an insufficient number of IT staff. (...)The intent is to ensure compliance with corporate and regulatory requirements, prevent value leakage and mitigate outsourcing risks.' However the modality of outsourcing changed continuously over time. Whilst formerly outsourcing megadeals hit the headlines, more recently selective sourcing contracts were

closed. The respective outsourcing arrangement depends on strategic considerations as well as on location, number and financial dependency of service providers, whereas service levels widely differ. Especially new technologies – like cloud computing, virtualization, etc. – enable new forms of IT outsourcing in a more dynamic and flexible way. According to Leimeister et al. (2010), cloud computing is defined as an ‘IT outsourcing model for the on-demand, online delivery of scalable IT services on the basis of virtualization technology and pay-per-use pricing models’. The IT Governance Institute (2011) refers to this development: ‘Respondents reported that their heads were in the cloud: 60 percent use or are planning to use cloud computing for non-mission-critical IT services, and more than 40 percent use or are planning to use it for mission-critical IT services.’ These statements indicate that, no matter what trend catches on or where the development will go, the sourcing question persists. Therefore, the aim of this dissertation is to follow an integrated approach to assess sourcing decisions of IT projects and portfolios. Therefore, cash flows, in terms of cost and benefits, risk as well as interdependencies are taken into account. The evaluation of sourcing decisions, considering their economic value contribution, supports a viable IT portfolio management in line with corporate objectives.

When applying scientific models to derive managerial decision support in the context of IT portfolio management, as the ones presented in this dissertation, the question arises how much effort should be put into the application of such models. In general it is questionable how much planning or methodical support is rewarding, since the application of certain techniques consumes time as well as resources. Feedback from practitioners during the research projects presented in chapter II has encouraged the examination of the process of estimating a project’s cash flows in this context. Therefore, this dissertation also addresses the question of how much effort should be put into the ex ante estimation of a software development project in chapter III. Increasing estimation accuracy presumably leads to a decreasing project’s risk, in terms of deviation of the actual project value from the estimated one. This risk reduction bears the chance of better resource allocation however it might be costly. Therefore, an optimal estimation effort can be identified, which allows for a further utilization of a project’s value creation potential. Therefore, chapter III contains another building block of a viable IT portfolio management in line with corporate objectives.

This dissertation examines IT project and portfolio sourcing decisions from different perspectives. First, it addresses sourcing decisions with fixed price contracts and examines the effect of bargaining power in this context. Then its focus is broadened to consider multivendor outsourcing decisions in general and cloud computing decisions in particular. To conclude it elaborates the topic of estimation accuracy. Therewith it contributes to an integrated IT portfolio management which enables value creation through and by IT. This is of great significance to practitioners as well as to researchers, since IT provides a basis and acts as driver for future developments in the global economy. In the following, the objectives and structure as well as the research questions addressed in this dissertation are outlined.

I.1 Objectives and Structure

This dissertation contributes to existing methods of IT portfolio management as a complementary tool set, addressing the sourcing of IT projects and portfolios and the optimization of estimation accuracy in software development projects. The aim of this work is to provide decision support based on a quantitative consideration of cash flows, risks and interdependencies and build a basis for empirical testing of the examined relations. Therefore, this work supports an integrated IT portfolio management according to value oriented principles. The structure and respective objectives of the chapters are outlined in the following table.

| | |
|------|---|
| I. | Introduction <ul style="list-style-type: none"> • Objective I.1: Overview regarding the content and structure of this dissertation • Objective I.2: Display of the addressed research questions |
| II. | Sourcing Decisions in IT Project and Portfolio Management <ul style="list-style-type: none"> • Objective II.1: Development of a quantitative model to evaluate fixed price IT outsourcing decisions of IT projects and portfolios • Objective II.2: Display of the effect of bargaining power in fixed price IT outsourcing decisions • Objective II.3: Development of a quantitative model to evaluate multivendor IT outsourcing decisions of IT projects and portfolios • Objective II.4: Description of a quantitative approach to evaluate multivendor IT outsourcing decisions of IT projects and portfolios • Objective II.5: Development of a quantitative model to evaluate multivendor portfolio decisions in cloud computing |
| III. | Optimization of Estimation Accuracy in Software Development Projects <ul style="list-style-type: none"> • Objective III.1: Development of a quantitative model to evaluate estimation accuracy for software development projects |
| IV. | Conclusion and Outlook <ul style="list-style-type: none"> • Objective IV.1: Summary of the findings • Objective IV.2: Description of links for future research |

I.2 Research Questions

The role of IT is central for the future development of the global economy. Therefore, an integrated and value oriented IT portfolio management is important for companies to survive and prosper in an increasingly dynamic environment. For about half a century, outsourcing of information technology has been a major topic in IT departments. Especially due to the rapidly changing business environment and increased competition, sourcing decisions are still of great importance. Many firms pursue outsourcing strategies to reduce costs and mitigate risks associated with their business processes (Lacity and Hirschheim 1993). IT service providers profit from this development and become more specialized and competitive (Currie 1997). This bears the opportunity for companies to close more lucrative outsourcing deals. Especially software development projects are affected by the outsourcing trend, which is influenced by recent developments - as for example the evolution of software development skills from being niche services to being global commodities (Dutta and Roy 2005; Lacity and Willcocks 2003; Lacity and Willcocks 2003). However, in the majority of companies, a practicable outsourcing strategy, considering cost, benefits, risk and interdependencies between IT projects, is either not clearly documented or only partially implemented. One reason for this might be, that some input parameters are difficult to determine, because project evaluation processes are neither specified nor documented. Therefore, many companies struggle with the implementation of an integrative outsourcing strategy and still have difficulties to succeed in the accomplishment of IT projects. Therefore, from a practical point of view, the aim of this dissertation is to provide quantitative decision support to managers evaluating IT outsourcing decisions as a further component of IT portfolio management methods. From a scientific point of view this dissertation provides a structuration of the research area and supports the deduction of new, empirically testable hypotheses. It further provides economic models which also should serve as a basis for empirical testing. The findings derived subsequently should provide a basis for design oriented progression to continuously improve the existing approaches and therewith the decision support in today's businesses. In this context article A1 entitled 'Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context' addresses the question:

Which degree of outsourcing should a client choose for a single project to minimize its risk adjusted costs? (RQ 1.1)

Since IT projects are not independent of each other because they might be based on the same processes or compete for the same resources, possible interactions have to be taken into account when deciding on their sourcing. Therefore, article A1 furthermore addresses the following research question:

Which degrees of outsourcing should a client choose for a given multiple projects portfolio to minimize the risk adjusted total portfolio costs? (RQ 1.2)

In practice usually the portfolio decision precedes the sourcing decision, which might bear additional optimization potential. Thus, article A1 also aims at answering the subsequent research question:

Is it more favorable to determine efficient outsourcing degrees for a previously selected optimal portfolio than to simultaneously select both, projects and their respective outsourcing degrees? (RQ 1.3)

Article A2 entitled ‘The Effect of Bargaining Power on Fixed Price IT Outsourcing Decisions’ builds upon the previous article A1 and enhances RQ 1.1 by a game theoretical analysis of the outsourcing decision. Therefore, the second research question of article A2 provides insights in the field of decision theory applied to the context of an outsourcing decision and therefore poses the following research question:

How does bargaining power affect this decision? (RQ 2.2)

Article A3 entitled ‘An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing’ deals with the topic from a different perspective, since companies increasingly extend their outsourcing strategies from single- to multisourcing aiming at the combination of best-of-breed vendors to deal with increased competitiveness and to react flexibly the changing economic conditions. Therefore, A3 addresses the subsequent research question:

Given a set of outsourcing vendors what is the optimal multivendor IT outsourcing strategy from a client’s perspective, i.e. which vendor should conduct which subproject? (RQ 3.1)

To analyze the effect of misestimating the input parameters of the model and to derive statement about the purpose of the assessment of a portfolio’s risk, A3 also aims at answering the following research questions:

How does the assessment of risk affect this decision? (RQ 3.2) How substantial is the error when neglecting risk? (RQ 3.3)

Since practical applicability of scientifically derived economic models is a prerequisite for design oriented research (Sein et al. 2011), article A4 entitled ‘Bewertung von IT-Multisourcing-Entscheidungen mit Methoden des Portfoliomanagements’ summarizes the findings of article A3 and provides a guideline for practitioners to implement quantitative decision support for multivendor outsourcing strategies. It implicitly puts the research question:

Which requirements must be met by a method for evaluating multisourcing decisions and how can application difficulties be overcome? (RQ 4.1)

Article A5 entitled ‘Multivendor Portfolio Strategies in Cloud Computing’ addresses the prevailing topic of cloud computing. Cloud computing, as a novel form of IT outsourcing, faces similar issues concerning the evaluation and selection of service provider portfolios as traditional IT outsourcing. However the specific risk structure of provider default has to be taken into account. Article A5 therefore poses this research question:

How can a cloud service provider portfolio be evaluated considering cost, cloud computing specific risk and interdependencies, thus contributing to a better understanding and exploitation of the economic potential of cloud computing? (RQ 5.1)

To provide guidance in the application of the economic model derived, article A5 therefore also considers the research questions stated below:

How can this model be applied by practitioners? (RQ 5.2) How can a client identify the optimal cloud computing portfolio allocation strategy? (RQ 5.3)

The formal-deductive models derived in article A1, A3 and A5 should provide an economic analysis of the respective research questions, which should serve as a basis for decision support in today's businesses as well as for further scientific investigation of IT outsourcing evaluation and vendor selection processes. They build constituent parts in a value oriented IT portfolio management and provide means for companies to cope with current and future challenges in a constantly evolving global economy driven by developments in information technology.

Another building block in a viable IT portfolio management is the process of estimating an IT project's cash flows prior to the implementation. The question about the existence of an optimal estimation effort arose during the examination of companies' current approaches of IT portfolio management. The estimation of the project value might impact the planning reliability concerning the resources assigned to the project. This risk reduction is beneficial, however, the estimation itself is costly. Therefore, an optimal estimation effort might exist. Article A6 entitled 'Optimization of Estimation Accuracy in Software Development Projects' provides an initial approach to the question:

What is the optimal estimation effort for a software development project? (RQ 6.1)

Hence, it is a first step towards decision support to determine the optimal estimation effort of a software development project in monetary units. This bears the potential of a more efficient resource allocation within the company. The focus of A6 is not to provide a model that is directly applicable in practice as a single means of decision support, it rather enhances existing decision processes by a quantitative aspect and supports the deduction of new, empirically testable hypotheses. It therefore supports an integrated IT portfolio management.

Chapter II and III present the articles described above. Chapter IV concludes with a summary of the findings derived and provides an investigation of possible future research questions.

I.3 References

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Maizlish, B., and Handler, R. 2005. „IT (Information Technology) Portfolio Management Step-by-Step: Unlocking the Business Value of Technology,” Wiley, Hoboken.

Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., and Lindgren, R. 2011. „Action Design Research,” MIS Quartely (35:1), pp. 37-56.

II Sourcing Decisions in IT Project and Portfolio Management

A viable IT portfolio management, which is in congruence with the company's objectives, is based upon value oriented principles. Therefore, sourcing decisions as one major challenge of ITPM have to be assessed economically. Chapter II comprises four papers addressing sourcing decisions in IT project and portfolio management monetarily. It includes the paper 'Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context' (A1) which is also published in Fridgen (2010) as well as the articles 'The Effect of Bargaining Power on Fixed Price IT Outsourcing Decisions' (A2), 'An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing' (A3), 'Bewertung von IT-Multisourcing-Entscheidungen mit Methoden des Portfoliomanagements' (A4) and 'Multivendor Portfolio Strategies in Cloud Computing' (A6).

II.1 Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context

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By optimizing its outsourcing strategy, a company faces the opportunity to lower the overall costs of its IT project portfolio. Without considering risk and diversification effects appropriately, companies make wrong decisions about how much of a project is reasonable to outsource. In this paper, we elaborate a model to identify a project's optimal degree of outsourcing at a fixed price, considering both, costs and risks of software development, as well as diversification effects. We also examine optimal outsourcing degrees in an IT portfolio context. To date, it is common practice to decide on the implementation of projects first and then decide on outsourcing. We provide a model that enables companies to determine an optimal outsourcing strategy which minimizes the total risk adjusted costs of an IT project portfolio by considering the portfolio decision and the selection of outsourcing degrees simultaneously. This model is then evaluated by simulation using real-world data.

Keywords: Outsourcing, IT Sourcing Portfolio Management, Portfolio Selection, Software Development Projects, Risk/Cost Valuation, Decision Model

II.1.1 Introduction

According to Lacity and Hirschheim (1993) firms pursue outsourcing strategies to reduce costs and mitigate risks associated with their business processes. Increased competition forces companies to deal with the cost cutting that is necessary to stay in business. Therefore, the market for outsourcing services increased significantly over time and is about to outgrow previous prospects (Aspray et al. 2006). IT service providers benefit from this development and become more specialized and competitive (Currie 1997). This provides the opportunity for companies to close more profitable outsourcing deals. Especially software development projects are affected, in consideration of the fact that today software development skills are global commodities (Dutta and Roy 2005; Lacity and Willcocks 2003). It is of particular importance for companies to identify a profitable software development outsourcing strategy, which encompasses not only strategic, but also economic and social perspectives (Lee et al. 2003). For the time being, in the majority of companies, a viable outsourcing strategy is either unknown or difficult to determine, because project evaluation processes are neither specified nor documented. Therefore, many companies struggle with the implementation of an integrative outsourcing strategy and still have difficulties to succeed in the implementation of IT projects. The Standish Group reports that two thirds of the IT projects fail or miss their targets (Standish Group 2006). On the contrary, Sauer et al. (2007) illustrate, when project risks are managed by a capable team, follow reasonable plans and tactics, and are of a manageable size, the outcomes are far better. To meet the desired requirement of making a project manageable, a project partitioning between a company and a service provider can be effective. Through outsourcing, projects can be managed more successfully (Slaughter and Ang 1996). Therefore, to enable a company to implement a profitable outsourcing strategy, we examine the effects of fixed price outsourcing on costs and risks of an IT project portfolio.

In today's IT departments it is common practice to decide on the implementation of individual projects first and then to decide case by case if and to what extent a project shall be outsourced. We illustrate that this causes inferior results compared to a simultaneous selection of projects and respective outsourcing degrees. For this purpose we demonstrate how a company can identify the optimal outsourcing degree of a single project as well as an optimal set of outsourcing degrees for a project portfolio. Moreover, we examine the selection of outsourcing degrees for a previously determined project portfolio and compare the results to an integrated portfolio selection and outsourcing decision. We thus provide a formal-deductive model that enables companies to determine an optimal outsourcing strategy by considering the project portfolio selection and the decision on outsourcing degrees simultaneously. The validity of our results is documented by a simulation based on data gathered in a business context. We point out that there are up to now no scientific papers addressing this special characteristic of outsourcing.

Subsequent to a brief survey of the essential literature, we describe the basic setting and assumptions of our approach. We first analyze a price negotiation between an outsourcing client and a service provider for a given degree of outsourcing. The risk-adjusted costs of a project constitute our objective function. From the objective function of a single project we deduce the one for multiple projects. We identify an optimal degree of outsourcing analytically – both, for a single project, as well as for an

optimal vector of outsourcing degrees of a project portfolio. Then, we demonstrate our findings in a two projects example. We evaluate our model through simulations with real-world data. First, after describing the simulation framework, we simulate a fixed multiple projects portfolio and identify the best outsourcing solution. Second, we determine an optimal project portfolio and subsequently identify its best combination of outsourcing degrees. Third, we compare these results with a simultaneously identified best portfolio and its respective outsourcing degrees. Finally, we address practical implications, limitations and prospects of our model.

II.1.2 Literature Overview

IT outsourcing is defined as the decision on relocating an IT department's tasks to a third party vendor, who conducts them and charges a certain fee for the service (Apte et al. 1997; Lacity and Hirschheim 1993; Loh and Venkatraman 1992). The reasons for IT outsourcing are manifold, e.g. excess human and technological resources, focusing on core competencies, and exploitation of global strategic advantages, just to name a few. But the main motive is the cost advantage outsourcing bears, if implemented appropriately (Dibbern et al. 2004; Lacity and Willcocks 1998; Standish Group 2006). To succeed in the implementation, firms need a strategy to manage the costs and risks of outsourcing decisions (Willcocks et al. 1999). In recent years, instead of closing „outsourcing megadeals“ selective outsourcing evolves, where companies decide deliberately on their outsourcing activities (Lacity et al. 1996). An integrated view of outsourcing, containing strategic, economic and social aspects, helps firms to realize the anticipated gains (Lee et al. 2003). Aron et al. (2005) coin the term „rightsourcing“, which means that a conscious risk and relationship management with multiple outsourcing vendors enables companies to reap benefits. Besides the cost and efficiency benefits, drawbacks have to be taken into account, when deciding on outsourcing. Outsourcing can entail disadvantages like unauthorized knowledge transfer, inflexibility though long term contracts, poor relationship management and accompanying poor loyalty and quality (Bryce and Useem 1998). These drawbacks must be included into the evaluation of outsourcing decisions. The costs and risks of outsourcing need to be assessed carefully. Different methods of estimating development costs are discussed in Boehm et al. (2000). The estimation of the associated risk is equally important. Many articles focus on the qualitative assessment of risk, for example Aron et al. (2005) and Willcocks et al. (1999), whereas few focus on the quantification and computation of risk, like Aubert et al. (1999).

Another research stream relevant for our contribution is the theory on transaction costs of outsourcing. Besides the risky costs of development, transaction costs occur, if a project is outsourced to an IT service provider (Aubert et al. 2004; Lammers 2004). These costs can be split into fixed and variable transaction costs. Fixed transaction costs occur as soon as certain projects or fractions of a project are outsourced, for example costs of negotiation and project initiation (Patel and Subrahmanyam 1982). Variable transaction costs are dependent on the magnitude of the fraction or project outsourced, e.g. costs of communication and control (Dibbern et al. 2006).

Investments in IT increased significantly over time, but the gains of successfully implemented IT projects are required to be managed alongside with the accompanying costs and risks, in order to reap worthwhile benefits. Therefore, firms are trying to establish a comprehensive IT portfolio management, in order to get the most advantageous rate of return (Oh et al. 2007; Weill and Aral 2005). But still,

shortfalls cause the failure of numerous IT projects (Standish Group 2006). Therefore, many papers address the issue of how to govern an IT project portfolio. Quantitative approaches on IT portfolio management, e.g. Verhoef (2005), work with economic theory such as the discounted cash flow but mostly omit interdependencies between projects. Some approaches model interdependencies by using Modern Portfolio Theory (MPT) (Butler et al. 1999; Santhanam and Kyparisis 1996). Zimmermann et al. (2008) for example adapt the MPT to propose a decision model for global IT sourcing decisions. They consider the costs of site/project combinations as risky and build a portfolio optimization model.

Like most of the aforementioned articles, our model does not consider the risk of outsourcing in its entirety (e.g. qualitative vs. quantitative risk, risk of costs vs. returns). Moreover, we only consider projects which fit into strategic considerations and passed the analysis of available resources and capabilities. In this model, we focus on one specific aspect of outsourcing. We provide an economic model that delivers relevant insights supporting the design of outsourcing decision processes in today's business.

II.1.3 Model

Our focus is the analysis of a situation where an outsourcing client tries to optimize the software development outsourcing strategy by minimizing the risk adjusted total costs generated by a certain project portfolio. For reasons of simplicity we focus on costs of outsourcing only, as we consider the outsourcing client's cash inflows from a certain project to be independent from whether fractions of the projects are outsourced or not. For this paper, we model outsourcing as a fixed price and thus risk-free alternative for project development that can be used to control IT portfolio risk. Thereby, we define risk as a negative or positive deviation from an expected value (as common in finance). This corresponds to a business setting, where a contract between the outsourcing client and the vendor assures characteristics and price of the service. By outsourcing a fraction of a software development project at a fixed price, the associated risk (according to our definition) can be conveyed to the vendor. By combining internal and external development of all projects in an efficient way, the risk adjusted costs of the IT project portfolio can be lowered to a minimum. To the best of our knowledge there are no further publications regarding this effect, so this is the first contribution to this area.

In the following, each portfolio consists of a limited number of projects, each of which can be only conducted once. We consider two parties, a client as initiator of an IT project, and an IT service provider as possible contractor for partial or entire project development. For each single project, the client has to decide on the fraction that is outsourced to the IT service provider. The size of an outsourced fraction, in the following referred to as outsourcing degree, is our decision variable. We analyze if the appropriate selection of an outsourcing degree, which means an optimal combination of internal and external project development, has effects on the risk adjusted costs of a single project or a project portfolio.

We only consider development activities, which can be outsourced. Essential project phases, which have to be accomplished internally, are not taken into account. For example, we exclude tasks concerning core competencies of the client, which cannot be outsourced, as well as crucial project phases, e.g. requirements analysis. Especially the department which initiated the software request is

essentially involved in the development process, at least by participating in the specification of the desired outcomes, like software characteristics concerning functionality and quality (Lacity et al. 1996).

For a better understanding, we provide a rough overview over the influencing parameters below, before we start specifying our assumptions. Since we focus on the costs of outsourcing only, we consider the outsourcing client's cash inflows on a certain project to be constant without considering the modality of development. The service provider's cash inflows are given by a certain reward he obtains for his work performed, in the following referred to as price for the externally developed fraction. In addition to the price, outsourcing a fraction of a project causes transaction costs at the client's side, which we consider risk-free. Table 1 provides a rough overview of the values relevant to the decisions of the respective party.

Table 1. Overview of the Setting

| | Outsourcing Client | Service Provider |
|-----------------|--|--|
| Risky costs | <ul style="list-style-type: none"> Costs of the internally developed fraction of a project | <ul style="list-style-type: none"> Costs of the fraction of a project developed on behalf of the client |
| Risk-free costs | <ul style="list-style-type: none"> Price for the externally developed fraction of a project Fixed and variable transaction costs | <ul style="list-style-type: none"> -- |
| Sum | <ul style="list-style-type: none"> A project's risk-adjusted costs | <ul style="list-style-type: none"> Costs of the fraction of a project developed on behalf of the client |
| Cash inflow | <ul style="list-style-type: none"> Cash inflow of a project | <ul style="list-style-type: none"> Price for externally developed fraction of a project |

To distinguish the parameters of the two parties, we introduce n as a subscript representing internal, client-related variables and x as a subscript representing external, service provider-related variables. The variable $g = (1, \dots, m)$ is a subscript referencing an arbitrary but definite project, with for example $g = 7$ for project #7. As stated above, the internal costs caused by a certain project are risky. The outsourcing client wants to outsource a fraction of a project to minimize the risk adjusted costs of development. To model this situation, we make the following simplifying assumption 1:

Assumption 1

The costs of an entire project g are $C_{n,g}$ for internal development at the client's responsibility and $C_{x,g}$ for external development at the service provider's responsibility. Both are normally distributed, i.e. $C_{n,g} \sim N(\mu_{n,g}, \sigma_{n,g})$ and $C_{x,g} \sim N(\mu_{x,g}, \sigma_{x,g})$.

To decide under which conditions an outsourcing agreement is advantageous for the parties involved, we have to model the pricing of an outsourced project that, in reality, would be subject to negotiation. The outcome of this price assessment for each single project is determined by the client's and the provider's decision rules, which are specified by their respective risk adjusted costs as described in assumption 2:

Assumption 2

The risk adjusted costs are measured by both parties and follow the general structure $\Phi = \mu - \alpha\sigma^2$ with μ denoting the expected value of the costs, σ denoting its standard deviation. We define $\alpha < 0$ as the parameter of risk aversion. The outsourcing client and the service provider are risk-averse regarding costs. The risk adjusted costs of the outsourcing client shall be minimized.

The risk adjusted costs correspond to a preference function which is developed according to established methods of decision theory and integrates an expected value, its deviation, and the decision maker's risk aversion. A related model has been developed by Freund (1956). It was applied in similar contexts over the last decades, for example by Hanink (1985) and Zimmermann et al. (2008). Since normally distributed random variables and risk-averse decision makers are considered, this preference function and its corresponding utility function are compatible to the Bernoulli principle (Bernoulli 1954; Franke and Hax 2004). The parameter α , $\alpha = -2\hat{\alpha}$, conforms to $\hat{\alpha}$, the Arrow-Pratt characterization of risk aversion (Arrow 1971), but since we focus on costs not on returns, the algebraic sign changes. Here, $\alpha < 0$ indicates risk aversion. The lower the value of α , the more risk-averse is the decision maker.

According to assumption 2, the risk adjusted costs of an entire single project g follow the structure $\Phi = \mu_{n,g} - \alpha_n \sigma_{n,g}^2$ for the outsourcing client and $\Phi = \mu_{x,g} - \alpha_{x,g} \sigma_{x,g}^2$ for the service provider, respectively. For reasons of simplicity and to be able to identify an efficient outsourcing degree, we state the following assumption 3:

Assumption 3

A project is infinitely divisible between internal and external development. Every fraction of a project is perfectly correlated to every other fraction. Equal sized fractions of a project carry the same risk.

In the past, due to interdependencies in development tasks, a project could not be cut into arbitrary pieces, several cohesive parts existed. Due to recent developments in computing concepts, like service oriented architectures, software development becomes more rapid, competitive, transparent and flexible. Formerly, complex and complicated amounts of source code were produced, nowadays distinct modules of software can be developed independently from each other. Therefore, the

assumption of divisibility, or at least a convergence to infinite divisibility, is justifiable. For example Zimmermann et al. (2008) make an analogous assumption.

As a consequence of assumption 3 there is a proportional relationship between the volume of a project's fraction and the costs and associated risks, respectively. This implies that the larger a considered fraction of a project, the higher the costs of development and the higher the associated standard deviation. This is obviously simplifying matters, as different phases of software projects naturally carry different risk and costs (Conrow and Shishido 1997). Nevertheless, a differentiation between project phases goes beyond the scope of this paper and is subject to further work in this area.

To identify the optimal degree of outsourcing, we define the decision variable λ_g , $0 \leq \lambda_g \leq 1$, as the percentage of a project's costs that refers to external development (at the service provider's responsibility). Therefore, $(1 - \lambda_g)$ is the percentage of a project's costs that refers to internal development (at the outsourcing client responsibility). The outsourcing degree $\lambda_g = 1$ stands for a project that is developed completely externally, $\lambda_g = 0$ for a project that is developed completely internally.

If a fraction of a project is outsourced to an IT service provider, transaction costs occur. These are for example costs of communication and coordination (Aubert et al. 2004). Transaction costs are either dependent on the fractions' size, or become due independently of the magnitude of the outsourced fraction. Therefore, we state the following assumption 4:

Assumption 4

When a project g is outsourced to a service provider with an outsourcing degree $\lambda_g > 0$, risk-free transaction costs $K(\lambda_g)$ occur, consisting of fixed transaction costs F_g and variable transaction costs $\lambda_g f_g$.

The fixed transaction costs are considered through a signum function¹. The variable transaction costs are composed of the cost factor f_g , multiplied with the volume of the outsourced fraction λ_g . Therefore, the term for the transaction costs follows the structure stated below.

$$K(\lambda_g) = \text{sgn}(\lambda_g)F_g + \lambda_g f_g \quad (1)$$

Transaction costs are risk-free and become due as soon as a fraction of a project is outsourced. Besides the transaction costs, the externally developed fraction causes costs to the outsourcing client in terms of a price $P(\lambda_g)$ that the service provider demands from the client for the service offered. The service provider and the client agree on this price, as well as on all specifications of the service, by contract.

¹ The signum function implies, that for $\lambda_g = 0$, the term for the fixed transaction costs turns 0. Then, the entire project is developed internally, thus no transaction costs occur. For $\lambda_g > 0$, the term turns 1, i.e. if fractions of the project are outsourced. Then, the full amount of fixed transaction costs becomes due (Courant and John 1965).

Assumption 5

The service's characteristics and quality, as well as a certain price, are contractually assured and carry no risk for the client.

As a consequence of assumptions 1, 3 and 5, the client's expected costs of a project g with an external developed fraction λ_g , have the distribution parameters $\mu_{n,g}(1 - \lambda_g)$ and $\sigma_{n,g}(1 - \lambda_g)$. The service provider's expected costs of a project g have the distribution parameters $\mu_{x,g}\lambda_g$ and $\sigma_{x,g}\lambda_g$, respectively.

The negotiation of the price for the externally developed fraction is, in reality, a process of several bargaining rounds, which are difficult to picture. However, the bargaining positions of the two parties can be modeled by inserting the aforementioned distribution parameters into the valuation equations. The pricing function for an outsourced project fraction is derived in the following section.

II.1.3.1 Price Assessment

We use the individual preferences of the two parties to serve as a valuation criterion. Therefore, the price is assessed on the basis of the risk adjusted costs of the client, on the one hand, and the risk adjusted costs of the service provider, on the other. As can be seen in Table 1, the risk adjusted costs of the client are made up of the internal risk adjusted development costs, the assessed price of the external fraction, and the transaction costs. In contrast, the risk adjusted costs of the service provider are made up of the external risk adjusted development costs, only. Consequently, for each project a price assessment according to the following scheme takes place.

The price $P(\lambda_g)$ for a certain externally developed fraction of a project g ranges between an upper bound $U(\lambda_g)$, determined by the client's willingness to pay, and a lower bound $L(\lambda_g)$, determined by the service provider's minimum asking price. Between these limits, the two parties agree on an assessment outcome.

The client's willingness to pay for the external developed fraction is determined by the risk adjusted costs the development of the external fraction would cause internally. The client determines his maximum price by evaluating the risk adjusted costs which would occur if he develops the entire project by himself. Therefore, the upper bound consists of the costs and risk of the supposed additionally internally developed fraction. The covariance between the costs of the already internally developed fraction $(1 - \lambda_g)$ and the supposed additionally internally developed fraction λ_g adjusts the aforementioned risk. Then, the sum of the transaction costs is subtracted. This concludes in the following formula 1:

$$\begin{aligned} U(\lambda_g) &= \mu_{n,g} \lambda_g - \alpha_n \left((\sigma_{n,g} \lambda_g)^2 + 2Cov((1 - \lambda_g)C_{n,g}, \lambda_g C_{n,g}) \right) - sgn(\lambda_g)F_g - \lambda_g f_g \\ \Leftrightarrow U(\lambda_g) &= \mu_{n,g} \lambda_g - \alpha_n (2\lambda_g - \lambda_g^2) \sigma_{n,g}^2 - sgn(\lambda_g)F_g - \lambda_g f_g. \end{aligned} \quad (2)$$

For a single project, the client is willing to agree on every contract with a price below $U(\lambda_g)$, whereby a preferably low price is aspired. If the price exceeds $U(\lambda_g)$, the client would prefer to develop the entire

project internally. If the price is equal to $U(\lambda_g)$, the client is indifferent between internal and external development.

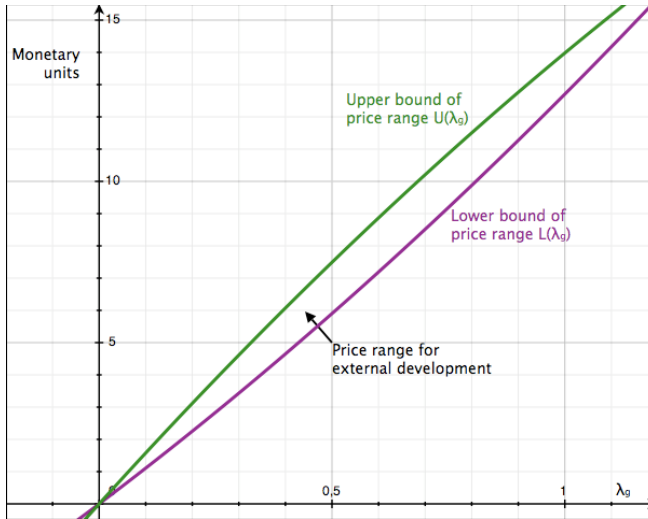
The price's lower bound is determined by the minimum price the service provider must achieve to obtain at least his risk adjusted costs, given the size of the fraction he is going to develop. The specific risk adjusted costs of the service provider are the following.

$$L(\lambda_g) = \mu_{x,g}\lambda_g - \alpha_{x,g}(\sigma_{x,g}\lambda_g)^2 \quad (3)$$

For a single project, the service provider is willing to agree upon every contract with a price above $L(\lambda_g)$, whereby a preferably high price is aspired. If the price falls below $L(\lambda_g)$, the service provider is not willing to enter the commitment. If the price is equal to $L(\lambda_g)$, the service provider is indifferent whether to close the contract or not.

Since we consider risk averse decision makers, the parameter α is negative. Therefore, $U(\lambda_g)$ is positive as long as fixed transaction costs do not outweigh the advantages of outsourcing and $L(\lambda_g)$ is always positive. If an agreement interval between the two borders exists, an outsourcing decision is favorable and a room to negotiate can be shared among the involved parties. This is the case only if $\exists \lambda_g$ with $U(\lambda_g) \geq L(\lambda_g)$. Figure 1 shows the upper and lower bounds and the resulting agreement interval (price range).

Figure 1. Price Range for External Development



Prior research offers different schemes of partitioning agreement intervals (Krapp and Wotschofsky 2004). This, however, goes beyond the scope of our paper. We present a very generic model that can be adapted to map different approaches. Therefore, we introduce the parameter γ_g . $\gamma_g \in]0; 1[$ indicates a specific pricing interval share of a party. An agreement with $\gamma_g = 0$ would indicate an outcome at the lower bound, which would be favored by the client, whereas for a single project the service provider would be indifferent between closing the contract or not. An agreement with $\gamma_g = 1$ would indicate an outcome at the upper bound, which would be favored by the service provider,

whereas for a single project the client would be indifferent between outsourcing and internal development of the specific project's fraction. These solutions are for the sole benefit of one party and thus not realistic. Therefore, we only consider $0 < \gamma_g < 1$.

Thus, the price $P(\lambda_g)$ of each externally developed fraction is determined by the following formula.

$$\begin{aligned} P(\lambda_g) &= \gamma_g \cdot U(\lambda_g) + (1 - \gamma_g) \cdot L(\lambda_g) \\ &= \gamma_g (\mu_{n,g} \lambda_g - \alpha_n (2\lambda_g - \lambda_g^2) \sigma_{n,g}^2 - \text{sgn}(\lambda_g) F_g - \lambda_g f_g) + (1 - \gamma_g) (\mu_{x,g} \lambda_g - \alpha_{x,g} (\sigma_{x,g} \lambda_g)^2) \end{aligned} \quad (4)$$

$P(\lambda_g)$ depends on the existence of an agreement interval, therefore it is only defined for $\{\lambda_g | U(\lambda_g) \geq L(\lambda_g)\}$. For reasons of simplicity and to avoid case differentiations in the following we presume that $P(\lambda_g)$ is defined for all outsourcing degrees² $0 \leq \lambda_g \leq 1$.

II.1.3.2 Derivation of the Objective Function

The client's risk adjusted costs of development constitute the objective function which is to be minimized by choosing an optimal λ_g . They consist of the risky internal development costs and risk-free terms for transaction costs and the assessed price. The term of the transaction costs follows equation (1). The price term follows equation (4). We regard these functions and all variables besides λ_g as exogenously given, and integrate them into the objective function.

Thus, the costs of single project g are represented by a normally distributed random variable with distribution parameters

$$\begin{aligned} M(\lambda_g) &= \mu_{n,g} (1 - \lambda_g) + P(\lambda_g) + K(\lambda_g) \\ &= \mu_{n,g} (1 - \lambda_g) + \gamma_g (\mu_{n,g} \lambda_g - \alpha_n (2\lambda_g - \lambda_g^2) \sigma_{n,g}^2 - \text{sgn}(\lambda_g) F_g - \lambda_g f_g) \\ &\quad + (1 - \gamma_g) (\mu_{x,g} \lambda_g - \alpha_{x,g} (\sigma_{x,g} \lambda_g)^2) + \text{sgn}(\lambda_g) F_g + \lambda_g f_g \end{aligned} \quad (5)$$

as expected value, and

$$S(\lambda_g) = \sqrt{(\sigma_{n,g} (1 - \lambda_g))^2} \quad (6)$$

as standard deviation. Therefore, with respect to assumption 2, a single project's risk adjusted costs are modeled according to the following structure.

$$\begin{aligned} \Phi(\lambda_g) &= M(\lambda_g) - \alpha_n (S(\lambda_g))^2 \\ &= \mu_{n,g} (1 - \lambda_g) + \gamma_g (\mu_{n,g} \lambda_g - \alpha_n (2\lambda_g - \lambda_g^2) \sigma_{n,g}^2 - \text{sgn}(\lambda_g) F_g - \lambda_g f_g) \\ &\quad + (1 - \gamma_g) (\mu_{x,g} \lambda_g - \alpha_{x,g} (\sigma_{x,g} \lambda_g)^2) + \text{sgn}(\lambda_g) F_g + \lambda_g f_g - \alpha_n (\sigma_{n,g} (1 - \lambda_g))^2 \end{aligned} \quad (7)$$

² Special calculational cases might occur in boundary areas of the upper and lower bound, thus a pricing interval might not exist. Since the market for specialized and competitive service providers is flourishing, we suppose that in reality an outsourcing vendor willing to provide the service can be found for any outsourcing degree. On this condition, a positive price interval exists for all relevant cases.

With multiple projects, the expected costs of the projects, the prices for external development, and the transaction costs are added up to the total portfolio costs. The indices i and j are referencing all projects $(1, \dots, m)$ considered in the portfolio. The vector $\vec{\lambda} = (\lambda_1, \dots, \lambda_m)$ contains the outsourcing degrees of all projects. Therefore, expected total portfolio costs are

$$M(\vec{\lambda}) = \sum_{i=1}^m M(\lambda_i) = \sum_{i=1}^m \mu_{n,i}(1 - \lambda_i) + \sum_{i=1}^m P(\lambda_i) + \sum_{i=1}^m K(\lambda_i). \quad (8)$$

However, there are dependencies between the different projects' costs that are accounted for using correlation coefficients $\rho_{i,j}$, $0 \leq \rho_{i,j} \leq 1$. Please note that we only consider positively correlated projects as a negative correlation of projects is uncommon in reality (this would mean that good performance of one project systematically causes bad performance of another and vice versa). The standard deviation of the total portfolio costs including the diversification effects is

$$S(\vec{\lambda}) = \sqrt{\sum_{i=1}^m \sum_{j=1}^m \sigma_{n,i}(1 - \lambda_i) \sigma_{n,j}(1 - \lambda_j) \rho_{i,j}}. \quad (9)$$

To simplify matters, we do not include diversification effects in the *pricing term* – neither for the outsourcing client, nor the service provider – as this might lead to complex variations of the upper and lower bound. Due to these effects the service provider might be able to offer a lower price and the outsourcing client might be willing to pay a higher price. Thus, the price range would be broader than stated above. Besides, diversification effects in the pricing term would raise questions about the sequence of project investments. Each project would change the portfolio which serves as evaluation basis for the subsequent price negotiation. These effects would amplify the complexity of our model. Since the characteristics of the pricing term would not change severely due to the inclusion of diversification effects, and since it would have low impact on the main results of this paper, we neglect these effects that however might be subject to further research.

Instead, we take the pricing term as given and focus on the client's point of view. Therefore, the price equation for a portfolio of projects is

$$\begin{aligned} P(\vec{\lambda}) &= \sum_{i=1}^m P(\lambda_i) \\ &= \sum_{i=1}^m \left(\gamma_i (\mu_{n,i} \lambda_i - \alpha_n (2\lambda_i - \lambda_i^2) \sigma_{n,i}^2 - \text{sgn}(\lambda_i) F_i - \lambda_i f_i) + (1 - \gamma_i) (\mu_{x,i} \lambda_i - \alpha_{x,i} (\sigma_{x,i} \lambda_i)^2) \right). \end{aligned} \quad (10)$$

Consequently, the risk adjusted total portfolio costs are modeled according to the following structure.

$$\Phi(\vec{\lambda}) = \sum_{i=1}^m \mu_{n,i}(1 - \lambda_i) \quad (11)$$

$$\begin{aligned}
& + \sum_{i=1}^m \left(\gamma_i (\mu_{n,i} \lambda_i - \alpha_n (2\lambda_i - \lambda_i^2) \sigma_{n,i}^2 - \text{sgn}(\lambda_i) F_i - \lambda_i f_i) + (1 - \gamma_i) (\mu_{x,i} \lambda_i - \alpha_{x,i} (\sigma_{x,i} \lambda_i)^2) \right) \\
& + \sum_{i=1}^m \text{sgn}(\lambda_i) F_i - \lambda_i f_i - \alpha_n \sum_{i=1}^m \sum_{j=1}^m \sigma_{n,i} (1 - \lambda_i) \sigma_{n,j} (1 - \lambda_j) \rho_{i,j}
\end{aligned}$$

Before exploring a situation where a company has to determine $\vec{\lambda}^* = (\lambda_1^*, \dots, \lambda_m^*)$ for multiple projects in a portfolio view, we initially focus on the determination of a single project's optimal outsourcing degree. Considering a single project's internal development costs and the price paid for an externally developed fraction, the client faces many different internal/external development compositions, i.e. different values for λ_g , to get to the desired outcome of implementing a certain project. Therefore, to provide a basis for the following extensions of our model, a first research question can be posed: *Which degree of outsourcing should a client choose for a single project to minimize the risk adjusted costs of a software development project?*

II.1.3.3 Outsourcing of a Single Project

In this section the client considers only one software development project g . As an equation containing a signum function is not continuously differentiable, we address the fixed transaction costs later on, when we simulate the results for multiple projects. For now, to be able to solve the optimization problem analytically, we set the fixed transaction costs $F_g = 0$.

The formation of the objective function to be minimized for a single project follows the scheme pictured in the previous section. In the first step we neglect that $\lambda_g \in [0,1]$ to obtain a possible minimal solution $\hat{\lambda}_g$. To fulfill the first order condition for optimality, we set the first derivative with respect to λ_g equal to 0.

$$\frac{\partial \Phi(\lambda_g)}{\partial \lambda_g} = (1 - \gamma_g) (f_g - \mu_{n,g} + \mu_{x,g} - 2(\alpha_n (-1 + \lambda_g) \sigma_{n,g}^2 + \alpha_{x,g} \lambda_g \sigma_{x,g}^2)) = 0 \quad (12)$$

We solve the equation for λ_g and get

$$\hat{\lambda}_g = \frac{f_g - \mu_{n,g} + \mu_{x,g} + 2\alpha_n \sigma_{n,g}^2}{2\alpha_n \sigma_{n,g}^2 + 2\alpha_{x,g} \sigma_{x,g}^2}. \quad (13)$$

To fulfill the second order condition, the second derivative with respect to λ_g has to be larger than zero.

$$\frac{\partial^2 \Phi(\lambda_g)}{\partial \lambda_g^2} = 2(-1 + \gamma_g) (\alpha_n \sigma_{n,g}^2 + \alpha_{x,g} \sigma_{x,g}^2) > 0 \quad (14)$$

To obtain a global minimum neglecting that $\lambda_g \in [0,1]$, the first and second order conditions have to be fulfilled. With all exogenous parameters in the previously defined domains, the second order condition (formula 14) is always true. Accounting for $\lambda_g \in [0,1]$, the parameter $\lambda_g^* = \hat{\lambda}_g$ constitutes an

optimum, only if $\hat{\lambda}_g \in [0,1]$. If $\hat{\lambda}_g$ takes values below zero or larger than 1, we choose the optimal solutions $\lambda_g^* = 0$ for any $\hat{\lambda}_g < 0$, and $\lambda_g^* = 1$ for any $\hat{\lambda}_g > 1$.

In equation (13) the denominator, consisting of the combined risks of internal and external development, is always negative, since the parameter for risk aversion α is below zero. Regarding the numerator, the algebraic sign can change with a shift in costs. It shows the variable transaction costs, the spread between internal and external development costs, and the risk associated with internal development, adjusted by the parameter for risk aversion. This means that costs caused by outsourcing are compared to costs caused by internal development. If the costs of outsourcing outweigh the costs of internal development, the numerator turns positive. Hence, $\hat{\lambda}_g \leq 0 \Rightarrow \lambda_g^* = 0$, which means that no outsourcing occurs. Else, if the costs of internal development outweigh the costs of outsourcing, the numerator turns negative. So, $\hat{\lambda}_g$ and λ_g^* turn larger than zero which means that outsourcing occurs. The magnitude of the determined optimal outsourcing degree depends on the risk adjusted cost advantage of either development option.

Figure 2. Optimal Outsourcing Degree of a Single Project

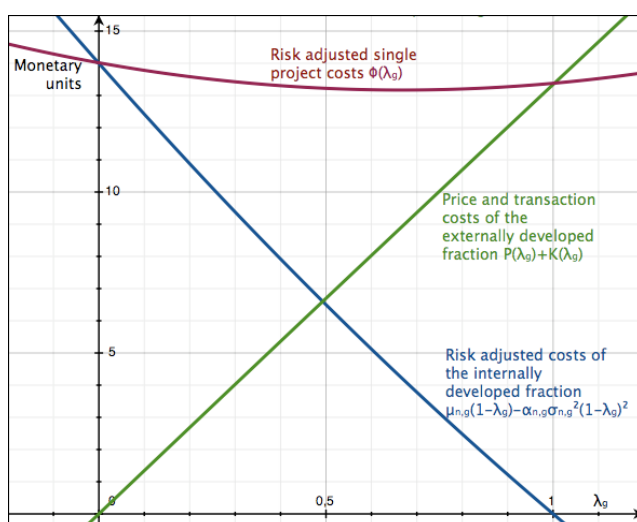


Figure 2 shows the decreasing risk adjusted internal development costs and the increasing price for the outsourced fraction subject to an increasing outsourcing degree. The overall risk adjusted costs of a single project are shown as aggregation of the two slopes, in the upper part of the chart. There, the optimal outsourcing degree can be identified at the curves minimum.

The optimal outsourcing degree is determined by the minimal risk adjusted costs. In the following, we expand our model to identify optimal outsourcing degrees of projects within a portfolio. Since companies conduct multiple projects simultaneously, we capture a multiple projects portfolio in the following section. Therefore, a second research question can be posed: *Which degrees of outsourcing should a client choose for a given multiple projects portfolio to minimize the risk adjusted total portfolio costs?*

II.1.3.4 Outsourcing of a Multiple Projects Portfolio

The client considers multiple software development projects in a portfolio. In the following, we want to determine the optimal outsourcing degrees of projects analytically within a portfolio view. As stated in the single project scenario, for reasons of simplicity, fixed transaction costs are not considered. Besides that, the objective function is still built according to the principles stated above.

We now face a multivariate optimization problem with a vector of decision variables $\vec{\lambda} = (\lambda_1, \dots, \lambda_m)$. Again, in the first step we neglect that $\vec{\lambda} \in [0,1]^m$ to obtain the vector $\vec{\lambda}$ that contains a possible minimal solution. The first order condition for optimality with respect to every, arbitrary but definite λ_g with $g = (1, \dots, m)$ follows the structure

$$\begin{aligned} \frac{\partial \Phi(\vec{\lambda})}{\partial \lambda_g} &= f_g - f_g \gamma_g + (-1 + \gamma_g) \mu_{n,g} + (1 - \gamma_g) \mu_{x,g} \\ &+ 2 \left(\alpha_n \sigma_{n,g} \left((-1 + \lambda_g) \gamma_g \sigma_{n,g} - \sum_{j=1}^m (-1 + \lambda_j) \sigma_{n,j} \rho_{g,j} \right) + \alpha_{x,g} (-1 + \gamma_g) \lambda_g \sigma_{x,g}^2 \right) = 0. \end{aligned} \quad (15)$$

Solving this equation³ for every λ_g we get $\vec{\lambda}$. To analyze the curvature, we have to build a Hessian matrix, consisting of all second order partial derivatives of the objective function. Differentiating twice with respect to any λ_g , the second order partial derivatives follow the structure

$$\frac{\partial^2 \Phi(\vec{\lambda})}{\partial \lambda_g^2} = 2(\alpha_n (\gamma_g - \rho_{g,g}) \sigma_{n,g}^2 + \alpha_{x,g} (-1 + \gamma_g) \sigma_{x,g}^2). \quad (16)$$

They form the main diagonal of the Hessian matrix. The second order partial derivatives of the objective function with respect to any $\lambda_g \lambda_h$, with h as subscript referencing another arbitrary but definite project and $g \neq h$, follow the structure

$$\frac{\partial^2 \Phi(\vec{\lambda})}{\partial \lambda_g \partial \lambda_h} = -2\alpha_n \sigma_{n,g} \sigma_{n,h} \rho_{g,h}. \quad (17)$$

Apart from the main diagonal, they form the lower and upper triangular matrix of the Hessian matrix, which is built according to the following scheme.

$$H = \begin{pmatrix} \frac{\partial^2 \Phi(\vec{\lambda})}{\partial \lambda_1^2} & \dots & \frac{\partial^2 \Phi(\vec{\lambda})}{\partial \lambda_1 \lambda_m} \\ \vdots & \ddots & \vdots \\ \frac{\partial^2 \Phi(\vec{\lambda})}{\partial \lambda_m \lambda_1} & \dots & \frac{\partial^2 \Phi(\vec{\lambda})}{\partial \lambda_m^2} \end{pmatrix} \quad (18)$$

³ The equation is obviously difficult to solve for λ_g in general. See equations (19) and (20) for an example on two projects.

To obtain a global minimum neglecting that $\vec{\lambda} \in [0,1]^m$, the first and second order conditions have to be fulfilled. The second order condition demands that the Hessian matrix has to be positive definite, which is always true with all exogenous parameters in the previously defined domains, since $\vec{\lambda}^T H \vec{\lambda} > 0$ for any $\vec{\lambda} \neq \mathbf{0}$. Accounting for $\vec{\lambda} \in [0,1]^m$, the vector $\vec{\lambda}^* = \vec{\lambda}$ constitutes an optimum, if $\vec{\lambda} \in [0,1]^m$. If any element of $\vec{\lambda}$, e.g. $\hat{\lambda}_g$, takes values below zero or larger than 1 the optimal solution is more complex to determine. On independent examination – as stated in the single project view – the solutions $\lambda_g^* = 0$, or $\lambda_g^* = 1$, respectively would be favorable for any individual project g . Nevertheless, due to the form of the objective function $\Phi(\vec{\lambda})$, every element of $\vec{\lambda}$ depends on all other elements of $\vec{\lambda}$ in an optimal portfolio. Therefore, the optimality of the objective function cannot be assured when adapting a single λ_g . As nonlinear optimization goes beyond the scope of this paper we assume for the following two projects example $\vec{\lambda} \in [0,1]^2$. Later on, we overcome this problem and the assumption $F_g = 0$ by using simulation.

Two Projects Example

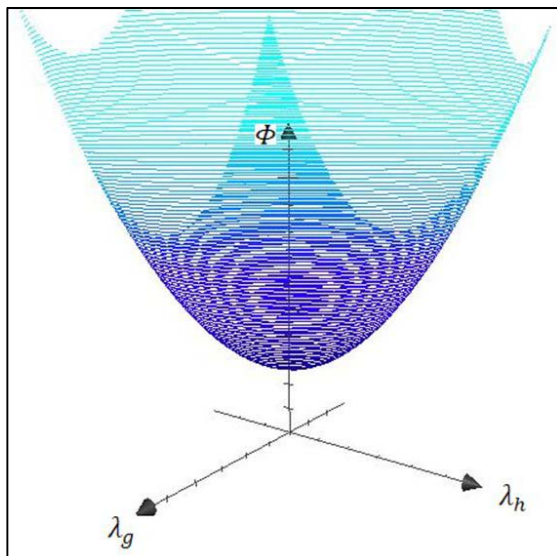
We now analyze a two projects setting for the projects g and h , respectively. Figure 3 shows the total risk adjusted costs of a two projects portfolio subject to two outsourcing degrees λ_g and λ_h .

The total risk adjusted costs minimizing outsourcing degrees, λ_g^* and λ_h^* , can be quantified as follows

$$\lambda_g^* = \frac{f_g(-1 + \gamma_g) + \mu_{n,g} - \gamma_g \mu_{n,g} + (-1 + \gamma_g) \mu_{x,g} + 2\alpha_n \sigma_{n,g}((\gamma_g - 1)\sigma_{n,g} + (-1 + \lambda_h^*)\rho_{g,h}\sigma_{n,h})}{2(\alpha_n(\gamma_g - 1)\sigma_{n,g}^2 + \alpha_{x,g}(-1 + \gamma_g)\sigma_{x,g}^2)} \quad (19)$$

and

$$\lambda_h^* = \frac{f_h(-1 + \gamma_h) + \mu_{n,h} - \gamma_h \mu_{n,h} + (-1 + \gamma_h) \mu_{x,h} + 2\alpha_n \sigma_{n,h}((\gamma_h - 1)\sigma_{n,h} + (-1 + \lambda_g^*)\rho_{g,h}\sigma_{n,g})}{2(\alpha_n(\gamma_h - 1)\sigma_{n,h}^2 + \alpha_{x,h}(-1 + \gamma_h)\sigma_{x,h}^2)} \quad (20)$$

Figure 3. Optimal Outsourcing Degrees of Two Projects

As stated in the single project view, the denominators of both, λ_g^* and λ_h^* , are always negative, the extension by constants do not change any findings. The numerator contains the spread in risk-adjusted costs of outsourcing and internal development and is of either sign depending on the profitability of either option.

In the previous sections we do not take fixed transaction costs into consideration. Therefore, our results favor outsourcing even on condition that the fixed transaction costs exceed the savings due to outsourcing. Moreover, with our analytical approach we are not able to assure solutions within the domain of $\vec{\lambda}^*$ in every case. To eliminate such distortions and to provide more findings, we will use simulations in the following.

Framework for the Simulations

For the findings shown in the following sections, we generated a set of project parameters and outsourcing reference values to run the simulations, pictured in the graphs below. We suggested the following input parameters for twelve projects: expected costs, standard deviations, parameters of risk aversion, price assessment outcomes, correlation coefficients and fixed/variable transaction costs. For the estimates we adopted the proportions of the expected values and standard deviations of Zimmermann et al. (2008). The values are based on real business case data of a major IT service provider, whose identity is disguised for reasons of confidentiality. The correlation coefficients are randomly generated, equally distributed numbers between 0 and 1. For reasons of comparability we assumed equal returns of all projects. For the outsourcing degrees, we created 24,000 equally distributed reference values for each project. The probabilities of *no outsourcing* and *total outsourcing* were manually set to 5% each. Otherwise, these realistic decisions would be underrepresented in our random numbers.

For simplifying matters of expression, we use the term „efficient“ for non-dominated results of our simulation, although we are aware of the fact that they could be dominated by results of a full enumeration or an analytical optimization (either one of them is very difficult to realize, therefore we proceed with a simulation).

Outsourcing of Multiple Projects within a Fixed Project Portfolio

The client considers $Q = 12$ given software development projects in a portfolio. The expected values and standard deviations of the 12-projects-portfolio with different outsourcing degrees are shown in the following diagram.

Figure 4. Fixed Project Portfolio with Random Outsourcing Degrees

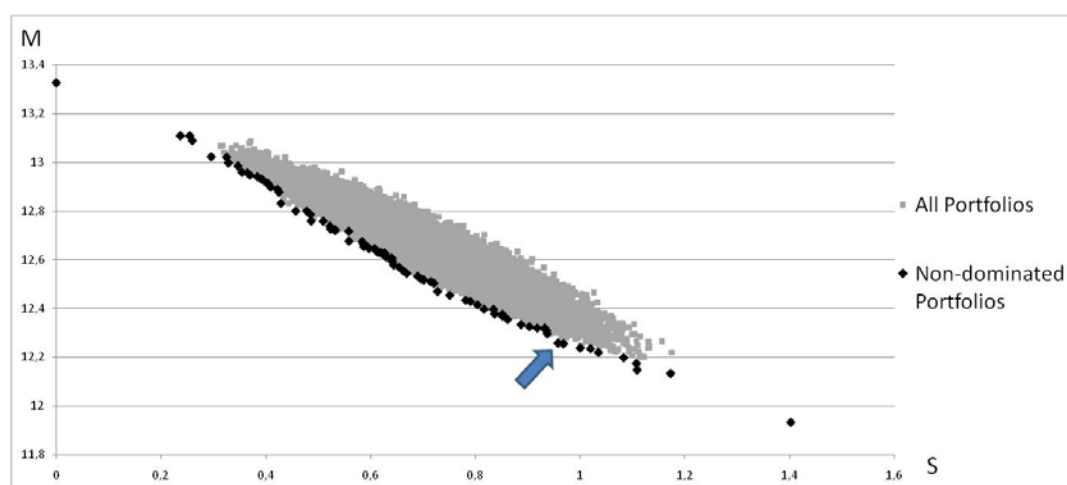


Figure 4 shows a scatter plot of possible outsourcing alternatives for the fixed portfolio. A frontier of efficient portfolios is shown in dark grey. If the outsourcing client considers portfolio dependencies in the selection of the outsourcing degrees, a superior solution can be achieved. The arrow indicates the portfolio with the best allocation of outsourcing degrees identified during the simulation, which is the portfolio with the lowest risk adjusted total costs, amounting to $\Phi = 12.7169$. These solutions are only non-dominated but not necessarily optimal, because results are derived by simulation and not by optimization.

So far, we only considered a given set of projects and combined them into one portfolio and plotted it with multiple outsourcing degrees. However, a client faces multiple options to choose from and to build an efficient project portfolio. Therefore, we will picture the portfolio choice process and show its effects on the best solution. Therefore, a fourth research question can be posed: *Is it more favorable to determine efficient outsourcing degrees for a previously selected optimal portfolio than to simultaneously select both, projects and their respective outsourcing degrees?*

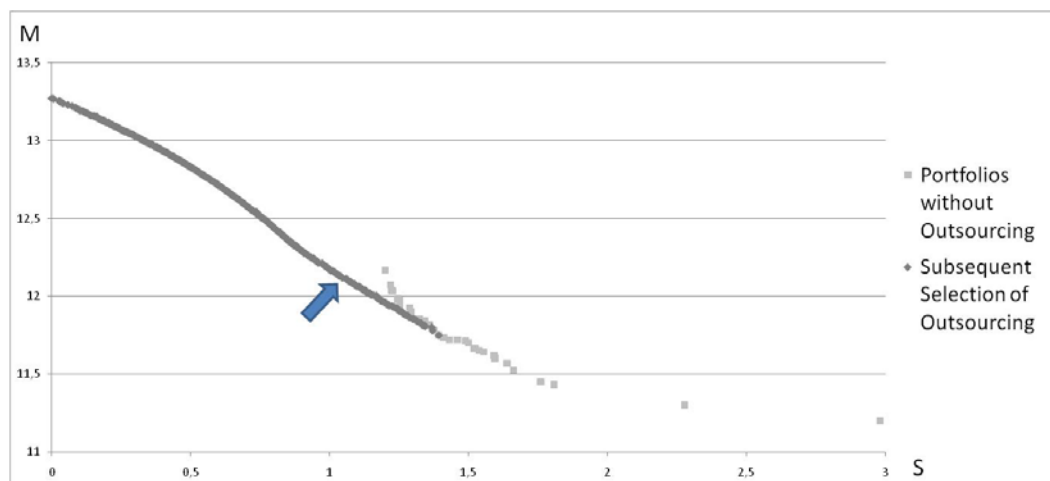
Outsourcing of Multiple Projects within an ex ante Determined Portfolio

To evaluate the first part of our research question, we consider a selection of an optimal project portfolio with q out of $Q = 12$ projects. We build the portfolios using complete enumeration then we

pick the optimal one, which is the portfolio with the lowest risk adjusted total costs. Subsequently, for each project within the optimal portfolio 24,000 random, equally distributed outsourcing degrees are determined by simulation. Amongst all possible outsourcing combinations the best portfolio solution is identified.

In figure 5, the light grey dots show all efficient expected value- and standard deviation- combinations of portfolio selections without outsourcing. The optimal portfolio has total risk adjusted costs $\Phi = 12.7192$. All efficient portfolio combinations of partially outsourced projects are pictured in medium grey. One can see that the portfolios of partially outsourced projects dominate several efficient portfolios without outsourcing and therefore might be favored by the client. The best portfolio solution with outsourcing amounting to $\Phi = 12.6664$, is again denoted by an arrow. The portfolio with outsourcing is superior (+0.42%) to the portfolio without outsourcing.

Figure 5. Subsequent Selection of Projects and Outsourcing



We examined an ex ante portfolio choice with a subsequent selection of outsourcing degrees. We now want to see if a simultaneous portfolio choice and selection of outsourcing degrees will lead to an even better solution.

Outsourcing of Multiple Projects with Simultaneous Portfolio Selection

In contrast to established business processes where outsourcing decisions are made after the decision on the composition of the project portfolio, we now choose q out of $Q = 12$ projects with their q outsourcing degrees simultaneously.

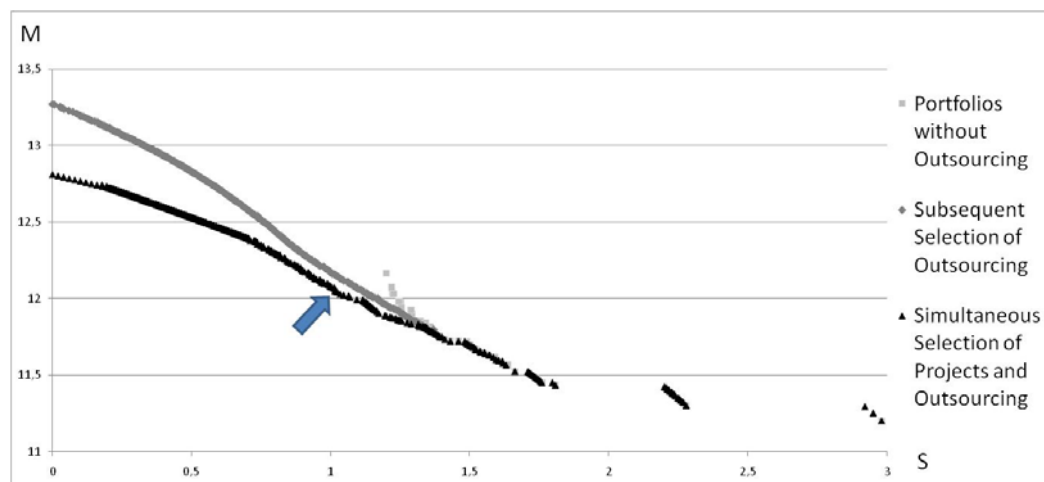
Figure 6. Simultaneous Selection of Projects and Outsourcing

Figure 6 shows a portfolio choice of q out of Q projects and **subsequent** selection of q individual outsourcing degrees for the predetermined portfolio projects as established in the previous paragraph. Furthermore it shows the **simultaneous** selection of q out of Q projects and q associated outsourcing degrees of all possible projects. This leads to portfolio compositions from which the best possible portfolio with $\Phi = 12.5638$ can be determined (indicated by an arrow). The simultaneous selection of projects and outsourcing degrees gets to a superior solution (+ 0.82%) compared to the subsequent selection, where only the outsourcing degrees of the predetermined portfolio are part of the simulation. Compared to the portfolio without outsourcing, the simultaneous selection of projects and outsourcing degrees is superior, too (+ 1.22%). Although the improvement might seem small at first sight, the benefit companies might realize should not be underestimated. Above, we compare our finally best portfolio to an already optimized portfolio without outsourcing, but to date, companies rarely use effective portfolio optimization to decide on outsourcing their IT projects. The reference values for comparison would therefore be lower in reality and the potential gains are higher. Furthermore, a major company with a corresponding IT budget might realize substantial absolute savings.

II.1.4 Practical Implications, Limitations and Conclusion

Today, companies increasingly realize the relevance of IT portfolio management in general as well as in the context of IT outsourcing. Thereby, they extend their focus from a pure cash-flow oriented view to a more generic one and integrate risk and dependencies into their decisions. Nevertheless, these approaches are often pragmatic and methodically weak. The vision of a value adding quantitative IT portfolio management requires methodically rigor models that deliver initial reasonable results, although they might not be suitable to be applied in practice without adjustments.

Although it bears great cost reduction potential, still little research exists in the field of fixed price outsourcing and its effects on an IT project portfolio. This paper provides a quantitative model to help companies to improve their IT outsourcing strategies. Including interdependencies between projects as well as transaction costs, we find that outsourcing an appropriate fraction of an IT project can enable a

company to minimize the risk adjusted costs of a project, as well as of a project portfolio. Moreover, we discover that the simultaneous selection of outsourcing degrees and best project portfolio may lead to even lower risk adjusted total costs than the subsequent determination of the best project portfolio and outsourcing degrees.

This is of special importance as today's IT decision processes mostly feature subsequent decisions only. Companies usually decide on projects first and then evaluate possible outsourcing settings. The restricting assumptions of this paper are necessary to show analytically that this bears optimization potential. Relaxing these restrictions would make an analytical solution impossible. But still, there is no obvious reason, why these effects should not occur. A business oriented model which is directly applicable but still methodically rigor will be the objective of further research in this area. Therefore, every limitation of this paper has to be addressed separately and analyzed profoundly.

First, the exclusion of risk for a fixed price outsourced fraction might not necessarily picture reality, because for example default risks remain. In terms of this paper, these additional risks could be pictured by introducing price and transaction costs as random variables. This leads to a gain in complexity because all correlations between in- and outsourced fractions would have to be considered. This major extension of the model is our current work-in-progress. It will also include the analysis of contract types, other than fixed price outsourcing. Furthermore, we currently neglect varying returns of projects and assume them to be constant regardless of the degree of outsourcing. The implementation of projects by a specialized service provider might however have positive and negative impacts on the return, e.g. through influences outlined in agency theory. This would provide a more eclectic picture of reality.

Also, we assume infinite divisibility of projects to be able to build continuous functions and their derivatives in order to derive our results analytically. However, one has to admit that dividing arbitrary parts of projects might be technically impossible or irrational concerning economical aspects. In contrast, discrete partitioning might lead to inferior absolute outcomes. Nevertheless, the model can be used to heuristically approximate discrete results as a basis for an in-depth analysis. Additionally, the linear relationship of the fraction's size to costs and risk, requested in assumption 3, might lead to a loss in generality, since different parts of a project might entail distinct values of costs and risks. Separate observation of different project parts with different risk/cost structures might be a practical addition. Moreover, we include risk diversification effects in the objective function, but neglect them in the price assessment – for both, the outsourcing client and the service provider. The effects on the price range might as well be subject to further model extensions. Finally, our model pictures ex ante decisions only. The development of an integrated model considering the existing project portfolio as well as the decision on additional projects might be of great significance to practitioners as well as to researchers.

Although the model pictures reality in a constrained way, it provides a basis for firms to plan and improve their outsourcing strategies. Thereby, it is not only of high relevance to business practice, but also provides a theoretically sound economical approach.

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II.2 The Effect of Bargaining Power on Fixed Price IT Outsourcing Decisions

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Successful IT outsourcing is usually for the benefit of both parties: the outsourcing client and the service provider. With a fixed price contract, the client tries to lower project risks and costs by transferring parts of a project to the service provider at a previously negotiated price. In this paper, we elaborate a model from the client's perspective to identify a project's optimal degree of outsourcing, considering both, costs and risks of software development. We then study the effect of bargaining power on this decision. Against the expectation that a powerful service provider demanding a higher price will cause a lower degree of outsourcing, the model shows that bargaining power has no effect on the decision. Instead, the client will choose the outsourcing degree at the maximum spread between the service provider's risk-adjusted cost and the risk-adjusted development cost of the client, no matter how the benefit will be shared between the two parties.

Keywords: IT-Outsourcing, Risk/Cost Valuation, Game Theory, Decision Theory

II.2.1 Introduction

According to Lacity and Hirschheim (1993) firms pursue outsourcing strategies to reduce costs and mitigate risks associated with their business processes. Increased competition forces companies to deal with the cost cutting that is necessary to stay in business. Therefore, the market for outsourcing services increased significantly over time and is about to outgrow previous prospects (Aspray et al. 2006). Especially software development projects are affected, in consideration of the fact that today software development skills are global commodities (Dutta and Roy 2005; Lacity and Willcocks 2003).

The Standish Group reports that still two thirds of IT projects fail or miss their targets (Standish Group 2009). Sauer et al. (2007) illustrate that when project risks are managed by a capable team, follow reasonable plans and tactics, and are of a manageable size, the outcomes are far better. To meet the desired requirement of making a project manageable, a project partitioning between a company and a service provider can be effective. Through outsourcing, projects can be managed more successfully (Slaughter and Ang 1996). IT service providers benefit from these developments and become more specialized and competitive (Currie 2000).

In this paper, we narrow our focus to fixed price outsourcing contracts, which can be used to transfer project risk and costs to a service provider for a previously negotiated price. We provide a formal-deductive model based upon decision theory and game theory that enables companies to determine an optimal outsourcing strategy by considering costs and risk of the project as well as the bargaining power of both parties.

Our research questions are: 1) *Which degree of outsourcing should a client choose to minimize the risk adjusted costs of a software development project?* 2) *How does bargaining power affect this decision?*

II.2.2 Literature Overview

IT outsourcing is defined as the decision on relocating an IT department's tasks to a third party vendor, who conducts them and charges a certain fee for the service (Lacity and Hirschheim 1993; Loh and Venkatraman 1992; Apte et al. 1997). The reasons for IT outsourcing are manifold, e.g. Di Romualdo and Gurbaxani (1998) identified three strategic intents for IT outsourcing, in particular IS improvement, business impact, and commercial exploitation. But the main motive is cost reduction (Standish Group 2009; Dibbern et al. 2004; Lacity and Willcocks 1998). Based on industry data, Han et al. (2005) show that outsourcing contributes positively to economic growth. To realize benefits on a company level, firms need a strategy to manage the costs and risks of outsourcing decisions (Willcocks et al. 1999; Nault 1997). In recent years, instead of closing „outsourcing megadeals“ selective outsourcing evolves, where companies decide deliberately on their outsourcing activities (Lacity et al. 1996). An integrated view of outsourcing, containing strategic, economic and social aspects, helps firms to realize the anticipated gains (Lee et al. 2003). Aron et al. (2005) coin the term „rightsourcing“, which means that a conscious risk and relationship management with multiple outsourcing vendors enables companies to reap benefits. Besides the cost and efficiency advantages from IT outsourcing, drawbacks have to be taken into account when deciding on outsourcing. Outsourcing can entail disadvantages like unauthorized knowledge transfer, inflexibility though long term contracts, poor relationship

management and accompanying poor loyalty and quality (Bryce and Useem 1998). These drawbacks must be included into the evaluation of outsourcing decisions. The costs and risks of outsourcing need to be assessed carefully (Dewan et al. 2007). Different methods of estimating development costs are discussed in Boehm et al. (2000). The estimation of the associated risk is equally important. Many articles focus on the qualitative assessment of risk, for example Aron et al. (2005) and Willcocks et al. (1999), whereas few focus on the quantification and computation of risk, like Aubert et al. (1999).

Outsourcing clients and service providers bargain on outsourcing contracts. As Gopal et al. (2003) evinced, the bargaining power has an influence on the type of contract. Since clients favor fixed price contracts in contrast to vendors who prefer time-and-materials contracts, a more powerful client might assert a fixed price contract, whereas a more powerful vendor might force through a time-and-materials contract. In a recent study Gopal and Koka (2010) find that there are many project settings where the vendor might also prefer fixed price contracts over the time-and-materials contracts. Susarla et al. (2010) analyze the role of ex ante contract design and develop strategies to overcome underinvestment in IT outsourcing. The profit sharing between the outsourcing client and the vendor is also dependent on bargaining power (Dey et al. 2010). Supplementary to these effects we examine the influence of bargaining power on the degree of outsourcing within a fixed price outsourcing contract. We provide an economic model that delivers relevant insights supporting the design of outsourcing decision processes in today's business.

II.2.3 Model

Our focus is on the analysis of a situation where an outsourcing client tries to minimize the risk adjusted total costs generated by a certain IT project. For reasons of simplicity, we consider the outsourcing client's cash inflows to be independent from whether fractions of the projects are outsourced or not, so we focus on costs of outsourcing only. We model outsourcing as a fixed price and thus risk-free alternative for project development. Thereby, we define risk as a negative or positive deviation from an expected value. This corresponds to a business setting where a contract between outsourcing client and vendor assures characteristics and price of the service. By outsourcing a fraction of a software development project at a fixed price, the associated risk (according to our definition) can be transferred to the vendor. Fridgen and Mueller (2009) already described this effect and how it can be used to lower the risk adjusted costs of an IT project portfolio to a minimum.

The client has to decide on the fraction that is outsourced to the IT service provider. The size of an outsourced fraction, which we refer to as outsourcing degree, is our decision variable. We only consider development activities which can be outsourced. Essential project phases, which have to be accomplished internally, are not taken into account.

For a better understanding, we provide a rough overview over the influencing parameters in Table 1, before we start specifying our assumptions.

Table 1. Overview of the Setting

| | Outsourcing Client | Service Provider |
|-----------------|--|---|
| Risky costs | <ul style="list-style-type: none"> Costs of the internally developed project fraction | <ul style="list-style-type: none"> Costs of the project fraction developed on behalf of the client |
| Risk-free costs | <ul style="list-style-type: none"> Price for the externally developed project fraction Transaction costs | <ul style="list-style-type: none"> none |
| Sum | <ul style="list-style-type: none"> A project's risk adjusted costs | <ul style="list-style-type: none"> Costs of the project fraction developed on behalf of the client |
| Cash inflow | <ul style="list-style-type: none"> Cash inflow of a project | <ul style="list-style-type: none"> Price for externally developed fraction of a project |

To distinguish the parameters of the two parties, we introduce n as a subscript representing internal, client-related variables and x as a subscript representing external, service provider-related variables. Therefore, the costs of the entire project are C_n for internal development at the client's responsibility and C_x for external development at the service provider's responsibility. As stated above, the costs caused by a certain project are risky. To model this situation, we make the following simplifying assumption 1:

Assumption 1 - C_n and C_x are normally distributed, i.e. $C_n \sim N(\mu_n, \sigma_n^2)$ and $C_x \sim N(\mu_x, \sigma_x^2)$.

Therefore, a project features certain expected costs (e.g. $\mu_n = \$2 \text{ Mio}$ for internal development, $\mu_x = \$1.8 \text{ Mio}$ for external development) and a certain positive or negative derivation from these expected costs (e.g. $\sigma_n = \$40,000$ for internal development, $\sigma_x = \$50,000$ for external development).

To decide under which conditions an outsourcing agreement is advantageous for the parties involved, we have to model the pricing of the outsourced project. The boundaries for this price assessment are determined by the client's and the provider's decision rules, which are specified by their respective risk adjusted costs as described in assumption 2:

Assumption 2 - The risk adjusted costs are measured by both parties and follow the general structure $\Phi = \mu + \alpha \sigma^2$ with μ denoting the expected value of the costs, σ denoting its standard deviation. We define $\alpha > 0$ as the parameter of risk aversion. The outsourcing client and the service provider are risk-averse regarding costs. The risk adjusted costs of the outsourcing client shall be minimized.

The risk adjusted costs correspond to a preference function which is developed according to established methods of decision theory and integrates an expected value, its deviation, and the decision maker's risk aversion. This preference function is based upon the utility function $U(x) =$

$-e^{2\alpha x}$ and due to assumptions 1 and 2 compatible to the Bernoulli principle (Bernoulli 1954). Its Arrow-Pratt characterization of absolute risk aversion (Arrow 1971) is -2α with $\alpha > 0$ modeling a risk-averse decision maker. The Arrow-Pratt characterization itself is negative because we model costs, not returns. A related model has been developed by Freund (1956). It was applied in similar contexts over the last decades, for example by Hanink (1985), Zimmermann et al. (2008) and Fridgen and Mueller (2009). According to assumption 2, the risk adjusted costs of an entire project follow the structure $\Phi_n = \mu_n + \alpha_n \sigma_n^2$ for the outsourcing client and $\Phi_x = \mu_x + \alpha_x \sigma_x^2$ for the service provider, respectively. Risk adjusted costs can be interpreted as the expected costs plus a premium for the borne risk (variance) which is weighted by the respective parameter of risk-aversion.

For reasons of simplicity and to be able to identify an efficient outsourcing degree, we state the following assumption 3:

Assumption 3 - *A project is infinitely divisible between internal and external development. Every fraction of a project is perfectly correlated to every other fraction. Equally sized fractions of a project carry the same risk.*

Due to recent developments in computing concepts, like service oriented architectures, software development becomes more rapid, competitive, transparent and flexible. Therefore, the assumption of divisibility, or at least a convergence to infinite divisibility, is justifiable. For example Zimmermann et al. (2008) make an analogous assumption.

As a consequence of assumption 3 there is a proportional relationship between the volume of a project's fraction and the costs and associated risks, respectively. This implies that the larger a considered fraction of a project, the higher the costs of development and the higher the associated standard deviation. This is obviously simplifying matters, as different phases of software projects naturally carry different risk and costs (Conrow and Shishido 1997). Nevertheless, a differentiation between project phases goes beyond the scope of this paper and is subject to further work in this area.

To identify the optimal degree of outsourcing, we define the decision variable $\lambda \in [0,1]$, as percentage of a project's costs that refers to external development (at the service provider's responsibility). Therefore, $(1 - \lambda)$ is the percentage of a project's costs that refers to internal development (at the outsourcing client's responsibility). The outsourcing degree $\lambda = 1$ stands for a project that is developed completely externally, $\lambda = 0$ for a project that is developed completely internally.

If a fraction of a project is outsourced to an IT service provider, transaction costs occur. These are for example costs of communication and coordination (Aubert et al. 2004). For reasons of simplicity we only consider transaction costs that are linearly dependent on the fractions' size. Therefore, we state the following assumption 4:

Assumption 4 - *When a project is outsourced to a service provider with an outsourcing degree $\lambda > 0$, risk-free variable transaction costs $K(\lambda) = \lambda f$ occur to the client.*

As we take the client's perspective we omit explicitly modeling the service provider's transaction costs in this paper. They can be seen as part of the service provider's expected costs.

Besides the transaction costs, the externally developed fraction causes costs for the outsourcing client in terms of a price $P(\lambda)$ that the service provider demands from the client for the service offered. The service provider and the client agree on this price, as well as on all specifications of the service, by contract.

Assumption 5 - *The service's characteristics and quality, as well as a certain price, are contractually assured and carry no risk for the client.*

Please note that this assumption rules out adverse selection as well as hold-up problems (that may be induced by incomplete contracts). Brynjolfsson (1994), for instance, applied the incomplete contracts approach to study the impact of contractibility on the boundaries of firms. Nam et al. (1996) and Wang et al. (1997) studied these effects in the outsourcing relationship context.

As a consequence of assumptions 1, 3 and 5, the client's costs of the project with an externally developed fraction λ , have the distribution parameters $\mu_n(1 - \lambda)$ and $\sigma_n^2(1 - \lambda)^2$. The service provider's expected costs of the project have the distribution parameters $\mu_x\lambda$ and $\sigma_x^2\lambda^2$, respectively.

II.2.3.1 Price Negotiation

We use the individual preferences of the two parties to serve as a valuation criterion for the pricing. Therefore, the price is assessed on the basis of the risk adjusted costs of the client, on the one hand, and the risk adjusted costs of the service provider, on the other. As can be seen in Table 1, the risk adjusted costs of the client are made up of the internal risk adjusted development costs, the assessed price of the external fraction, and the transaction costs. In contrast, the risk adjusted costs of the service provider are made up of the external risk adjusted development costs, only. Consequently, for each project a price assessment according to the following scheme takes place.

The price $P(\lambda)$ for a certain externally developed fraction of a project ranges between an upper bound $U(\lambda)$, determined by the client's willingness to pay, and a lower bound $L(\lambda)$, determined by the service provider's minimum asking price. Between these limits, the two parties agree on an assessment outcome.

The client's willingness to pay for the externally developed fraction is determined by the *risk adjusted costs* the development of the *external* fraction λ would cause *internally*. Therefore, the upper bound consists of the costs and risk of the supposed *additionally internally* developed fraction λ . Regarding the expected costs, this is straightforward. Regarding risk, the dependencies between the costs of the *already internally* developed fraction $(1 - \lambda)$ and the *supposed additionally internally* developed fraction λ has to be accounted for: With outsourcing, the client's risk is $(\sigma_n(1 - \lambda))^2$. Without outsourcing it is σ_n^2 . Outsourcing therefore lowers the client's risk by $\sigma_n^2 - (\sigma_n(1 - \lambda))^2$. Finally, transaction costs have to be subtracted. This concludes in the following formula 1:

$$\begin{aligned} U(\lambda) &= \mu_n \lambda + \alpha_n \left(\sigma_n^2 - (\sigma_n(1 - \lambda))^2 \right) - \lambda f \\ &= \mu_n \lambda + \alpha_n \sigma_n^2 (2\lambda - \lambda^2) - \lambda f \end{aligned} \tag{1}$$

For a single project, the client is willing to agree on every contract with a price below $U(\lambda)$, whereby a preferably low price is aspired. If the price exceeds $U(\lambda)$, the client would prefer to develop the entire project internally. If the price is equal to $U(\lambda)$, the client is indifferent between internal and external development. The price's lower bound is determined by the minimum price the service provider must achieve to obtain at least his risk adjusted costs, given the size of the fraction he is going to develop. The specific risk adjusted costs of the service provider are the following.

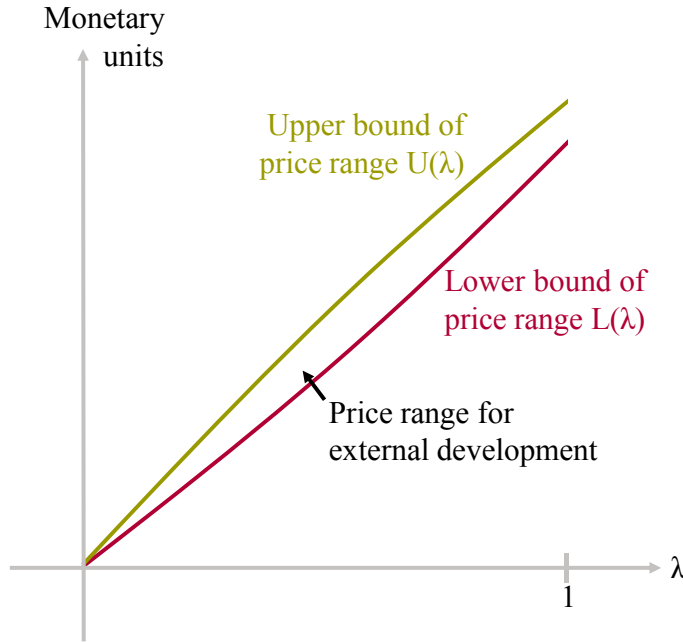
$$L(\lambda) = \mu_x \lambda + \alpha_x (\sigma_x \lambda)^2 \quad (2)$$

The service provider is willing to agree upon every contract with a price above $L(\lambda)$, whereby a preferably high price is aspired. If the price falls below $L(\lambda)$, the service provider is not willing to enter the commitment. If the price is equal to $L(\lambda)$, the service provider is indifferent whether to close the contract or not.

An agreement interval between client and service provider exists if $\exists \lambda \in [0; 1]: U(\lambda) > L(\lambda)$. Keeping in mind that $U(0) = L(0) = 0$ and determining the first derivatives of $U(\lambda)$ and $L(\lambda)$ for $\lambda \rightarrow 0$, we find that this condition is true for $\mu_n + 2\alpha_n \sigma_n^2 > \mu_x + f$. As a first result we record that the existence of an agreement interval is independent from the service provider's risk aversion and project risk.

Nevertheless, for reasons of simplicity and to avoid case differentiations in the following, we require $\forall \lambda \in [0; 1]: U(\lambda) \geq L(\lambda)$. This requirement is fulfilled for all λ if $\mu_n + \alpha_n \sigma_n^2 \geq \mu_x + \alpha_x \sigma_x^2 + f$. Therefore, an agreement interval exists for all considered outsourcing degrees if (for the entire project) the risk adjusted costs of the client outweigh (or equal) the risk adjusted costs of the service provider plus the transaction costs. Since the market for specialized and competitive service providers is flourishing (Michell and Fitzgerald 1997), we suppose that this condition is given for most real world cases.

Figure 1 shows the upper and lower bounds and the resulting agreement interval (price range).

Figure 1. Price Range for External Development

Having established the agreement interval, we now turn to the question what price $P(\lambda)$ both parties should agree on. In order to do so, we interpret the price negotiation as a cooperative game and determine a „fair“ partition of the agreement interval by applying game theoretic solution techniques. Both parties' payoff functions $u_n(\lambda)$, $u_x(\lambda)$ are given by the differences between $P(\lambda)$ and the respective risk adjusted costs. I.e., $u_n(\lambda) = U(\lambda) - P(\lambda)$ and $u_x(\lambda) = P(\lambda) - L(\lambda)$. It is easy to see that these payoff functions capture the gains from closing the contract. If, on the other hand, the two parties fail to reach a settlement, they only will receive their so-called disagreement payoffs $\underline{u} = (\underline{u}_n, \underline{u}_x)$. In the model presented here, failure of negotiations means that the project is developed completely internally and hence $\lambda = 0$. This obviously implies $u_n(0) = U(0) - P(0) = 0$ as well as $u_x(0) = P(0) - L(0) = 0$ and therefore $\underline{u} = (0,0)$.

If, on the other hand, client and service provider close the contract, the agreement interval $[L(\lambda), U(\lambda)]$ arises which we now strive to partition by setting $P(\lambda)$ adequately. One extreme case is an agreement where $P(\lambda) = L(\lambda)$ transfers the whole benefit to the client, yielding the allocation $(U(\lambda) - L(\lambda), 0)$. Contrarily, the allocation $(0, U(\lambda) - L(\lambda))$ results when $P(\lambda) = U(\lambda)$ transfers the whole benefit to the service provider. Besides these extreme scenarios, any convex combination of these allocations can be achieved by setting a fixed price $P(\lambda) \in [L(\lambda), U(\lambda)]$. Please note that these convex combinations can be interpreted as expected payoff vectors when the players agree to jointly randomized strategies. Since negotiations might fail, the disagreement point $\underline{u} = (\underline{u}_n, \underline{u}_x)$ can also be reached with positive probability. Hence, all convex combinations of these three allocations are feasible outcomes. Let us term this convex polyhedron Δ the feasible set of the bargaining game.

We now strive to identify the allocation $(\hat{u}_n, \hat{u}_x) \in \Delta$ that should be selected as a result of negotiations. Similar to Nash (1950), we approach this problem axiomatically. I.e. we generate a list of properties that a reasonable bargaining solution ought to satisfy and use these properties to determine the bargaining solution. Since our axiom system differs somewhat from the one proposed by Nash (our solution, for instance, does not rely on an axiom of symmetry), we summarize briefly the solution technique used in this paper.

Our first axiom requires that neither player gets less in the bargaining solution than he would in the disagreement case:

Axiom 1 (Individual Rationality) - (\hat{u}_n, \hat{u}_x) is individually rational, i.e. $\hat{u}_n \geq \underline{u}_n$ and $\hat{u}_x \geq \underline{u}_x$.

Since the bargaining game under consideration is a cooperative game, also collective (rather than individual) rationality considerations are relevant. We hence assert that a reasonable solution should be Pareto optimal:

Axiom 2 (Efficiency) - (\hat{u}_n, \hat{u}_x) is efficient, i.e. no $(u_n, u_x) \in \Delta$ exists with $(u_n, u_x) \neq (\hat{u}_n, \hat{u}_x)$, $u_n \geq \hat{u}_n$, and $u_x \geq \hat{u}_x$.

Our last axiom is a direct consequence of assumptions 1 and 2. Since the preference functions used in our model are compatible to the Bernoulli principle, increasing affine utility transformations (that alter origin and unit of utility) represent the same preference orderings. Therefore, a sensible bargaining solution ought to be invariant to varying ways of measuring utility. I.e., the solution should change in the same way:

Axiom 3 (Scale Invariance) - Let (\hat{u}_n, \hat{u}_x) be the solution to a bargaining game with feasible set Δ and disagreement point \underline{u} . Now consider a rescaled bargaining game with feasible set Δ' and disagreement point \underline{u}' where $\Delta \ni (u_n, u_x) \mapsto (a_n + b_n u_n, a_x + b_x u_x) \in \Delta'$, $\underline{u} = (\underline{u}_n, \underline{u}_x) \mapsto (a_n + b_n \underline{u}_n, a_x + b_x \underline{u}_x) = \underline{u}'$, and $b_n, b_x > 0$. Then, the solution to the rescaled bargaining game is given by $(a_n + b_n \hat{u}_n, a_x + b_x \hat{u}_x)$.

Axioms 1 through 3 are undisputed in cooperative game theory, cf. e.g. Nash (1950), Kalai and Smorodinski (1975), and Shapley (1953). Another common assertion („independence of irrelevant alternatives“) claims that eliminating feasible alternatives other than the disagreement point (that would not have been chosen) should not affect the solution. Because irrelevant alternatives do not exist in our model, we refrain from formulating an appropriate axiom.

As Kalai (1977) showed, every two-party bargaining game with a compact convex feasible set Δ and disagreement point $\underline{u} = (\underline{u}_n, \underline{u}_x)$ that satisfies axioms 1 through 3 as well as independence of irrelevant alternatives has a unique solution $(\hat{u}_n, \hat{u}_x) \in \Delta$. This solution is the point that maximizes $(\hat{u}_n - \underline{u}_n)^{1-\gamma} (\hat{u}_x - \underline{u}_x)^\gamma$ over all individually rational points in Δ and is called nonsymmetric Nash solution. Please note that the parameter $\gamma \in]0,1[$ reflects the bargaining power of the parties: Here, higher values of γ indicate more bargaining power of the service provider relatively to the client.

Now we apply the nonsymmetric Nash solution to determine the price $P(\lambda)$ for a certain externally developed fraction of the project. Since failure of negotiations implies $\lambda = 0$ and hence $\underline{u} = (0,0)$, the maximization problem to be solved simplifies as follows.

$$(\hat{u}_n - \underline{u}_n)^{1-\gamma} (\hat{u}_x - \underline{u}_x)^\gamma = (U(\lambda) - P(\lambda))^{1-\gamma} (P(\lambda) - L(\lambda))^\gamma \quad (3)$$

We now compute the nonsymmetric Nash solution by maximizing the right-hand side of equation (3) with respect to $P(\lambda)$. The first order condition is equivalent to

$$\gamma(U(\lambda) - P(\lambda))^{1-\gamma} (P(\lambda) - L(\lambda))^{\gamma-1} = (1-\gamma)(U(\lambda) - P(\lambda))^{-\gamma} (P(\lambda) - L(\lambda))^\gamma. \quad (4)$$

Agreements resulting in $P(\lambda) = L(\lambda)$ or $P(\lambda) = U(\lambda)$ are for the sole benefit of one party and thus not realistic. In addition to that, these solutions would involve case differentiations when solving equation (4) for $P(\lambda)$. Therefore, we only consider $L(\lambda) < P(\lambda) < U(\lambda)$. Straightforward algebra then yields

$$P(\lambda) = \gamma \cdot U(\lambda) + (1-\gamma) \cdot L(\lambda). \quad (5)$$

For reasons of space, we only remark that the second order condition is fulfilled, i.e. the second derivative of equation (3) with respect to $P(\lambda)$ is negative.

Please note that the price $P(\lambda)$ is a strictly increasing function of γ . Hence, γ indeed quantifies the service provider's bargaining power. Substituting formulae (1) and (2) into equation (5), we finally arrive at the following explicit characterization of the price $P(\lambda)$ of each externally developed fraction.

$$P(\lambda) = \gamma(\mu_n \lambda + \alpha_n \sigma_n^2 (2\lambda - \lambda^2) - \lambda f) + (1-\gamma)(\mu_x \lambda + \alpha_x (\sigma_x \lambda)^2) \quad (6)$$

II.2.3.2 Derivation of the Objective Function

The client's risk adjusted costs of development constitute the objective function which is to be minimized by choosing an optimal λ . It consists of the risky internal development costs, the risk-free transaction costs, and the assessed price. The transaction costs follow the term described in assumption 4. The pricing term follows equation (6). We regard these functions and all variables besides λ as exogenously given and integrate them into the objective function. Thus, the costs of our project are represented by a normally distributed random variable with the expected value

$$\begin{aligned} M(\lambda) &= \mu_n(1-\lambda) + K(\lambda) + P(\lambda) \\ &= \mu_n(1-\lambda) + \lambda f + \gamma(\mu_n \lambda + \alpha_n \sigma_n^2 (2\lambda - \lambda^2) - \lambda f) + (1-\gamma)(\mu_x \lambda + \alpha_x (\sigma_x \lambda)^2) \end{aligned} \quad (7)$$

and standard deviation

$$S(\lambda) = \sqrt{(\sigma_n(1-\lambda))^2} = \sigma_n(1-\lambda). \quad (8)$$

Therefore, using assumption 2, the project's risk adjusted costs are modeled according to the following structure.

$$\begin{aligned}
\Phi(\lambda) &= M(\lambda) + \alpha_n (S(\lambda))^2 \\
&= \mu_n(1 - \lambda) + \lambda f + \gamma(\mu_n \lambda + \alpha_n \sigma_n^2(2\lambda - \lambda^2) - \lambda f) + (1 - \gamma)(\mu_x \lambda + \alpha_x (\sigma_x \lambda)^2) \\
&\quad + \alpha_n (\sigma_n(1 - \lambda))^2
\end{aligned} \tag{9}$$

After several algebraic transformations, equation (9) can be rewritten:

$$\begin{aligned}
\Phi(\lambda) &= \mu_n + \alpha_n \sigma_n^2 - (1 - \gamma)((\mu_n \lambda + \alpha_n \sigma_n^2(2\lambda - \lambda^2) - \lambda f) - (\mu_x \lambda + \alpha_x (\sigma_x \lambda)^2)) \\
&= \Phi_n - (1 - \gamma)(U(\lambda) - L(\lambda))
\end{aligned} \tag{10}$$

As a result, equation (10) can be interpreted as follows: The risk-adjusted costs for a certain outsourcing degree $\Phi(\lambda)$ equal the client's risk-adjusted costs for the whole project Φ_n less the share $1 - \gamma$ (reflecting the bargaining power) of the spread between $U(\lambda)$ and $L(\lambda)$, which in turn can be interpreted as the overall benefit from outsourcing.

II.2.3.3 Optimization and Analysis

To obtain a first candidate $\hat{\lambda}$ for a minimal solution, we neglect that $\lambda \in [0,1]$. To fulfill the first order condition for optimality, we set the first derivative with respect to λ equal to 0.

$$\frac{\partial \Phi(\lambda)}{\partial \lambda} = (1 - \gamma)(f - \mu_n + \mu_x - 2\alpha_n \sigma_n^2(1 - \lambda) + 2\alpha_x \sigma_x^2 \lambda) = 0 \tag{11}$$

We solve the equation for λ and get

$$\hat{\lambda} = \frac{\mu_n + 2\alpha_n \sigma_n^2 - (\mu_x + f)}{2\alpha_n \sigma_n^2 + 2\alpha_x \sigma_x^2}. \tag{12}$$

To fulfill the second order condition, the second derivative with respect to λ has to be > 0 .

$$\frac{\partial^2 \Phi(\lambda)}{\partial \lambda^2} = 2(1 - \gamma)(\alpha_n \sigma_n^2 + \alpha_x \sigma_x^2) > 0 \tag{13}$$

With all exogenous parameters in the previously defined domains, the second order condition (13) is always true. Accounting for $\lambda \in [0,1]$, the parameter $\lambda^* = \hat{\lambda}$ constitutes an optimum, only if $\hat{\lambda} \in [0,1]$. Regarding equation (12), numerator and denominator are always positive, if an agreement interval exists (see section „price negotiation“). If $\hat{\lambda}$ takes values larger than 1, we choose the optimal solution $\lambda^* = 1$ for any $\hat{\lambda} > 1$ (cf. research question 1).

The client's expected costs μ_n and risk σ_n for the whole project, as well as the client's risk aversion α_n are positively linked to a higher outsourcing degree, transaction costs are negatively linked. Since $2\alpha_n \sigma_n^2$ is an additive term in numerator and denominator the outsourcing degree $\hat{\lambda} \in [0,1]$ increases for increasing risk aversion α_n or risk σ_n^2 . Quite intuitively, a client will prefer to outsource more fractions of a project if his expected costs, risk, or risk aversion increase or if the transaction costs decrease.

The service provider's expected costs μ_x and risk σ_x for the whole project, as well as the service provider's risk aversion α_x are negatively linked to $\hat{\lambda}$. This is comprehensible, too: the higher the service provider's expected costs, risk, and risk aversion, the lower the incentive to outsource.

Most interesting, the bargaining power γ has no influence on the optimal outsourcing degree at all (cf. research question 2). This can be interpreted best considering equation (10): The client actually maximizes the overall benefit from outsourcing $U(\lambda) - L(\lambda)$. This is reasonable, as the client gets a fixed share $1 - \gamma$ (reflecting the bargaining power) of this benefit for any chosen λ . Obviously, the bargaining power γ is irrelevant for the maximization of $U(\lambda) - L(\lambda)$ and therewith for the decision on the degree of outsourcing.

II.2.4 Limitations

Today, companies extend their focus from a pure cash-flow oriented view to a more generic one and integrate risk and dependencies into their decisions. Nevertheless, these approaches are often pragmatic and methodically weak. The vision of a value adding quantitative IT governance concerning risk and return requires methodically rigorous models that deliver initial reasonable results, although they might not be suitable to be applied in practice without adjustments. Therefore, a business-oriented model which is directly applicable but still methodically rigorous as well as an empirical analysis based upon real-world data will be the objective of future research. Thus, the limitations of this paper have to be addressed separately and analyzed profoundly.

First, the exclusion of risk for a fixed price outsourced fraction might not necessarily picture reality. We could also include the analysis of contract types other than fixed price. Furthermore, we currently neglect varying returns of projects and assume them to be constant regardless of the degree of outsourcing. Including e.g. comparative advantages of the service provider would provide a more eclectic picture of reality. Additionally, the linear relationship of the fraction's size to costs and risk, requested in assumption 3, might lead to a loss in generality, since different parts of a project might entail distinct values of costs and risks. Separate observation of different project parts with different risk/cost structures might be a practical addition.

Moreover, the inclusion of information asymmetries, e.g. with regard to the service's characteristics and quality, would provide insights into the incentive effects of outsourcing contracts. We expect that agency costs will then reduce the agreement interval. This topic indeed calls for further investigation and is therefore on our research agenda.

Concerning the bargaining model, we assume the two parties to be the only involved in the bargaining process and therefore omit the possibility of negotiating with other service providers. The effect of a fallback option for the client other than refraining from outsourcing still has to be examined.

II.2.5 Conclusion and Outlook

With this paper, we provide a model to determine the optimal degree for outsourcing a project at a fixed price. We find that within a fixed price outsourcing contract, the client strives to maximize the

overall benefit from outsourcing. This does not depend on the client's bargaining power which is therefore irrelevant for the decision on the optimal degree of outsourcing. The major extension of this model and therewith the focus of our future research will be the investigation of bargaining power on outsourcing decisions in a portfolio context. If the outsourcing decision is to be taken on multiple projects, how will the bargaining power of either the client or the vendor(s) influence it?

Although this model pictures reality in a constrained way, it provides a basis for firms to plan and improve their outsourcing strategies. Thereby, it is not only of high relevance to business practice, but also provides a theoretically sound economical approach.

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II.3 An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing

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Companies increasingly extend their outsourcing strategies from single-sourcing to multisourcing combining best-of-breed vendors. This paper includes an analytical model to evaluate a company's multisourcing strategy. The model can be applied for decision support to answer the questions, how many and which outsourcing vendors to integrate in the implementation of an IT project. We identify an optimal vendor portfolio considering monetary benefits and risk diversification as well as transaction costs arising from the integration and coordination of outsourcing vendors. Based upon a simulation, we find that it makes good economic sense to include a risk evaluation into the multisourcing decision process even if it is subject to misestimation. Therewith, companies are able to avoid unnecessary high risk and consequently a possible high damage. Furthermore, we find that it is better to be too cautious in risk assessment than to be too negligent.

Keywords: Multisourcing, multi-vendor outsourcing, portfolio management, analytic model

II.3.1 Introduction

According to Dibbern et al. (2004) firms pursue outsourcing strategies to reduce costs and mitigate risks associated with their business processes. Increased competition forces companies to deal with the cost cutting which is necessary to stay in business. Therefore, the market for outsourcing services increased significantly over time and is about to outgrow previous prospects (Aspray et al. 2006). IT outsourcing vendors benefit from this development and become more specialized and competitive (Lacity et al. 2009). This provides the opportunity for companies to close more profitable outsourcing deals with vendors that are experts in the respective area. Especially software development projects are affected, in consideration of the fact that today software development skills are global commodities (Dutta and Roy 2005; Lacity and Willcocks 2003). It is of particular importance for companies to identify a profitable software development outsourcing strategy, which encompasses not only strategic, but also economic and social perspectives (Lee et al. 2003). For the time being, in the majority of companies, a viable outsourcing strategy is either unknown or difficult to determine, because project evaluation processes are neither specified nor documented. Therefore, many companies struggle with the execution of an integrative outsourcing strategy and still have difficulties to succeed in the implementation of IT projects. On the contrary, Sauer et al. (2007) illustrate, when project risks are managed by a capable team, follow reasonable plans and tactics, and are of a manageable size, the outcomes are far better. To meet the desired requirement of managing an IT project profitably, multisourcing evolves as a capable strategy (Cohen and Young 2006; Levina and Su 2008; Oshri et al. 2009). The principal reasons for multisourcing from a client's perspective are increased bargaining power and better performance of the vendors (Lee et al. 2009).

Bapna et al. (2010) examine the dependencies of multiple vendors who are competitors and co-workers at the same time. All vendors who participate in the same project have to rely on each other's performance to meet the client's requirements. Little research has addressed this increased complexity. The authors demonstrate that „linear extensions of dyadic client-vendor IT outsourcing relationships are insufficient to capture the nuances of a multisourcing environment.“ They point out that further research shall address the characteristics of multi-vendor relations. As a first step, we examine a multisourcing strategy from a client's perspective and provide a model that helps the client to render multi-vendor IT outsourcing decisions.

The selection of IT outsourcing vendors is rarely conducted using quantitative methods and it is rarely taking cost, benefits, and risk into account. Especially a comprehensive risk assessment is still very scarce although multisourcing can offer important advantages in this respect. Sourcing IT to a single vendor might lower costs of coordination but the client „puts all eggs into one basket“. This is fraught with problems when it comes to a poor performance or even default of the chosen vendor. Furthermore, considering the complex dependencies within every IT project (Kundisch and Meier 2011) an unfortunate allocation of a single vendor to several essential subprojects can bear extreme risk for the project as a whole.

As today's decision makers oftentimes neglect the assessment of risk, it is very difficult to acquire data for an empirical evaluation. Especially the comparison of the respective projects' success and the used methods of risk assessment is demanding. Though, to generate further insights, we developed a formal

deductive economic model to provide an understanding of the importance of risk assessment in the multisourcing decision process. A common reason for neglecting risk is the fact that the estimation of risk is often prone to error and requires a considerable amount of time and money. Regarding the vendor selection process, we illustrate that even if risk is assessed with a substantial estimation error, much better project outcomes can be achieved than in a scenario without risk assessment.

From a practitioner's point of view, the model enables companies to improve their multisourcing strategy in an economic sense by considering costs, benefits, and risk of the decision. Our model shall not serve as a substitute for existing selection processes (see e.g. Cao and Wang 2007; Michell and Fitzgerald 1997; Wadhwa and Ravindran 2007) but it might do so as a complementary tool for decision support. As drawing normative conclusions from our model requires empirical evaluation, the data gathered from its application may be used to empirically evaluate its utility in the future.

Considering the aforementioned insights from research in multisourcing, transaction cost, and portfolio theory we pose the following research questions:

1. Given a set of outsourcing vendors what is the optimal multi-vendor IT outsourcing strategy from a client's perspective, i.e. which vendor should conduct which subproject?
2. How does the assessment of risk affect this decision? How substantial is the error when neglecting risk?

To the best of our knowledge there are no scientific papers addressing a quantitative portfolio selection as well as the importance of risk assessment in multi-vendor IT outsourcing.

Subsequent to a brief survey of the essential literature, we describe the basic setting and assumptions of our model. The risk-adjusted net present value of a project constitutes our objective function. We derive first results by the means of an analytical two subproject example. Then, we use a Monte Carlo simulation and identify the best multi-vendor IT outsourcing solutions. After describing the simulation framework, we evaluate and discuss the robustness of our model. To conclude, we derive results and address practical implications, limitations and prospects of our model.

II.3.2 Literature Overview

IT outsourcing is defined as the decision on relocating an IT department's tasks to a third party vendor, who conducts them and charges a certain fee for the service (Apte et al. 1997; Lacity and Hirschheim 1993; Loh and Venkatraman 1992). The reasons for IT outsourcing are manifold, e.g. Di Romualdo and Gurbaxani (1998) identified three strategic intents for IT outsourcing, in particular IS improvement, business impact, and commercial exploitation. But the main motive is the cost advantage outsourcing bears, if implemented appropriately (Dibbern et al. 2004; Lacity and Willcocks 1998). To succeed in the implementation, firms need a strategy to manage the costs, benefits and risks of outsourcing decisions (Nault 1997; Willcocks et al. 1999). An integrated view of outsourcing, containing strategic, economic and social aspects, helps firms to realize the anticipated gains (Lee et al. 2003). In the past fifteen years, instead of closing „outsourcing megadeals“ selective outsourcing evolved, where companies decide deliberately on their outsourcing activities (Lacity et al. 1996). Aron et al. (2005) coin the term

„rightsourcing“, which means that a conscious risk and relationship management with multiple outsourcing vendors enables companies to reap benefits. Therewith, outsourcing clients are able to combine the best-of-breed vendors to implement their IT strategy optimally (Bapna et al. 2010). Furthermore, developments in integration technologies lead to lower costs of technical integration and coordination, which facilitates the collaboration of numerous parties (Moitra and Ganesh 2005).

Besides the benefits, drawbacks have to be taken into account, when deciding on outsourcing (Dewan et al. 2007). Outsourcing can entail disadvantages like unauthorized knowledge transfer, inflexibility though long term contracts, poor relationship management and accompanying poor loyalty and quality (Bryce and Useem 1998). Also the choice of the outsourcing contract is relevant for outsourcing failure or success (Gopal et al. 2003; Susarla et al. 2010). Therefore, risk factors must be included into the evaluation of outsourcing decisions. Since the formerly mostly dyadic relationships of client and vendor evolved to complex relationships of client and multiple vendors, which implies dependencies on mutual performance and willingness of collaboration (Bapna et al. 2010; Cohen and Young 2006; Levina and Su 2008), interdependencies have to be considered when determining an IT project's risk. Many articles focus on the qualitative assessment of risk, for example Aron et al. (2005) and Willcocks et al. (1999), whereas few focus on the quantification and computation of risk, like Aubert et al. (1999). Due to the increased professionalism of outsourcing service providers there is a high potential of saving development time and cost reduction. When multi-vendor outsourcing is implemented appropriately, the specific risks of IT, such as project failure, time over-run, budget over-run and missing targets could be diminished.

In addition to the risky costs and benefits of development, transaction costs occur, if a project is outsourced to a vendor (Aubert et al. 2004; Lammers 2004). Transaction costs can be split into fixed and variable components, whereas fixed transaction costs occur as soon as certain projects or fractions of a project are outsourced, for example costs of negotiation and project initiation (Patel and Subrahmanyam 1982). Variable transaction costs depend on the magnitude of the fraction or project outsourced, e.g. costs of communication and control (Dibbern et al. 2006). For a brief survey of transaction cost economics and „extra cost“ evolving from client vendor relationships in the context of outsourcing see Dibbern et al. (2008).

Today, firms are trying to establish a comprehensive IT portfolio management, in order to get the most advantageous rates of risk and return (Oh et al. 2007; Weill and Aral 2005). Therefore, many papers address the issue of how to govern an IT project portfolio. Quantitative approaches on IT portfolio management, e.g. Verhoef (2005), work with economic theory such as the discounted cash flow but mostly omit interdependencies between projects. Some approaches model interdependencies by using portfolio theory (Butler et al. 1999; Santhanam and Kyparisis 1996). Zimmermann et al. (2008) for example adapt portfolio theory to propose a decision model for global IT sourcing decisions. They consider the costs of site and project combinations as risky and build a portfolio optimization model. Approaches which apply portfolio selection methods on multi-vendor IT outsourcing are scarce and mostly focus on programming issues like Chen and Cao (2009).

Similar to most of the aforementioned articles, our model does not consider the risk of outsourcing in its entirety (e.g. qualitative vs. quantitative risk, risk of costs vs. returns). We focus on risk as estimated

and computable variations of the net present values of IT (sub-) projects. Using this abstraction we are able to provide an economic model that delivers relevant insights supporting the design of outsourcing decision processes in today's businesses.

II.3.3 Model

Our focus is the analysis of a situation where an outsourcing client wants to optimize the IT outsourcing strategy considering multiple vendors. Therefore, we look at a set of outsourcing vendors V , v denoting an element of V . The project at hand consists of indivisible, consecutively numbered subprojects $s = 1..S$ which are all obligatory for the project's success. Without loss of generality, each subproject is assignable to any of the outsourcing vendors in V . The model is also capable of picturing in-house development; if a subproject is developed internally the client is modeled as one of the service providers.

We define the row vector $\vec{v} \in V^S$ as our decision vector. The column s of \vec{v} contains the selected vendor for subproject s . We define the function $v(s)$ to return the selected vendor for any subproject s . We model a subproject's net present value $\widehat{NPV}_{s,v}$ as a random variable depending on the respective outsourcing vendor.

By using the expected net present value and its standard deviation, we are able to capture all IT-specific risks albeit on an abstract level. The risk of budget overruns directly influences the amount of the cash outflows and can therefore be modeled by the standard deviation. Time overruns lead to delays in cash inflows. Even if a project fails or misses its targets cash out- and inflows vary accordingly. As over-estimating the required time or budget is also unfavorable, a two-sided risk measure like the standard deviation is applicable. Therefore, all kinds of IT specific risks are taken into account by considering a projects' $\widehat{NPV}_{s,v}$.

Regarding the decision on vendors for subprojects \vec{v} considering every subprojects' $\widehat{NPV}_{s,v}$, we make the following assumption 1:

Assumption 1: *The decision maker maximizes the entire project's risk adjusted net present value. The calculation of the risk adjusted net present value follows the general structure $\Phi = \mu - \alpha\sigma^2$. μ denotes the expected net present value; σ^2 denotes its variance as a measure of risk. We define α as the parameter of risk aversion and assume that the decision maker is risk-averse ($\alpha > 0$). The correlation between subprojects is depicted by the Bravais-Pearson correlation coefficients $\rho_{s,v,\hat{s},\hat{v}}$ for the respective subprojects s and \hat{s} as well as vendors v and \hat{v} .*

The risk adjusted net present value can be interpreted as the certainty equivalent of $\widehat{NPV}_{s,v}$ for normally distributed random variables and an exponential utility function and thus as a sum of money. This approach is in line with the Bernoulli principle and an established method of decision theory (Bernoulli 1738; Bernoulli 1954; Markowitz 1959; von Neumann and Morgenstern 1947). The parameter $\alpha > 0$ is a linear transformation of the Arrow-Pratt characterization of absolute risk aversion (Arrow 1971). The higher the value of α , the more risk-averse is the decision maker. A risk-averse decision maker favors the utility of a risk-free net present value over a risky net present value with

identical expected value. To determine the value of α , a company can draw on a market's utility function (competitors etc.) and thereof derive α (Kasanen and Trigeorgis 1994). Similar formal approaches and assumptions for risk adjusted economic value analysis have been derived by Longley-Cook (1998) and have been applied in the context of IT portfolios numerous times, for example in Bardhan et al. (2004), Fridgen and Mueller (2009), Hanink (1985), Fogelström et al. (2010), and Zimmermann et al. (2008).

As described above, outsourcing one or more subprojects to a certain vendor causes fixed and variable transaction costs. Assuming the variable transaction costs to be part of the respective $\widehat{NPV}_{s,v}$, we account for the fixed transaction costs by the following simplifying assumption 2:

Assumption 2: Each outsourcing vendor v conducting at least one subproject causes risk-free transaction costs k_v . The function $K(\vec{v})$ returns the sum of the transaction costs k_v for all distinct components of \vec{v} .

There might be real world situations where certain combinations of vendor and subproject are not practicable. For instance, a small company specialized on user-friendly front-end design is most probably not able to setup a complex database infrastructure. This issue can be covered by our model and the respective optimization algorithms through assuming prohibiting (e.g. infinite) values for the respective $\mu_{s,v}$ and $\sigma_{s,v}$.

Objective Function

A project's risk adjusted $\widehat{NPV}_{s,v}$ minus transaction costs constitutes the objective function which is to be maximized by choosing an optimal \vec{v} .

$$\Phi(\vec{v}) = \sum_{i=1}^S \mu_{i,v(i)} - \alpha \sum_{i=1}^S \sum_{j=1}^S \sigma_{i,v(i)} \sigma_{j,v(j)} \rho_{i,v(i),j,v(j)} - K(\vec{v})$$

With having a decision vector instead of a single decision variable, the model can be solved analytically for small problems only. This is due to the fact that all subproject-vendor combinations have to be analyzed and compared to each other individually. For example, with 4 subprojects and 5 vendors, $5^4 = 625$ different cases arise. Therefore, a full enumeration demands for computerized support. As real-world multi-vendor portfolio selection problems will be of a magnitude that can be handled by computers within seconds, a computer-aided full enumeration usually will be preferred to applying heuristics.

II.3.4 Model Evaluation

As described above, in today's companies a risk assessment, as requested by our model, is difficult to find. Consequently, at this point in time it is virtually impossible to acquire real world data to examine the benefits of risk assessment profoundly. However, as stated in the following, considerable advantages can be realized by applying the model. Therefore, companies might adopt it and a real world evaluation using case or field studies will be possible in the future.

According to Hevner et al.'s (2004) design science approach, an analytical evaluation or gathering data by simulation are legitimate means. For illustration and to derive first results for the mathematically interested reader, in a first step we analyze the setting of an IT project consisting of only two subprojects offered by two vendors analytically. Due to the model's complexity when applied on larger problems, an analytical evaluation is not auspicious. In a second step, for more complex project settings, we present and analyze the results of a Monte Carlo simulation.

II.3.4.1 Analytical Evaluation: Two Vendors and Two Subprojects

In the following, we examine the setting of an IT project consisting of two subprojects ($S = 2$) offered by two vendors ($V = \{A, B\}$). Consequently, \vec{v} may contain four different tuples:

$\vec{v} = (A, A)$, i.e. both subprojects are conducted by vendor A

$\vec{v} = (B, B)$, i.e. both subprojects are conducted by vendor B

$\vec{v} = (A, B)$, i.e. the first subproject is conducted by vendor A , the second by B

$\vec{v} = (B, A)$, i.e. the first subproject is conducted by vendor B , the second by A

For an optimization, it is necessary to compare the results of the objective functions $\Phi((A, A))$, $\Phi((B, B))$, $\Phi((A, B))$, $\Phi((B, A))$ and identify the \vec{v} with the maximum $\Phi(\vec{v})$. Therefore, we consider

$$\begin{aligned}\Phi((A, A)) &= \mu_{1,A} + \mu_{2,A} - \alpha(\sigma_{1,A}^2 + \sigma_{2,A}^2 + 2\sigma_{1,A}\sigma_{2,A}\rho_{1,A,2,A}) - k_A, \\ \Phi((B, B)) &= \mu_{1,B} + \mu_{2,B} - \alpha(\sigma_{1,B}^2 + \sigma_{2,B}^2 + 2\sigma_{1,B}\sigma_{2,B}\rho_{1,B,2,B}) - k_B, \\ \Phi((A, B)) &= \mu_{1,A} + \mu_{2,B} - \alpha(\sigma_{1,A}^2 + \sigma_{2,B}^2 + 2\sigma_{1,A}\sigma_{2,B}\rho_{1,A,2,B}) - k_A - k_B, \\ \Phi((B, A)) &= \mu_{1,B} + \mu_{2,A} - \alpha(\sigma_{1,B}^2 + \sigma_{2,A}^2 + 2\sigma_{1,B}\sigma_{2,A}\rho_{1,B,2,A}) - k_B - k_A.\end{aligned}$$

According to our research question, it is of particular interest, under which conditions the client favors the multiple vendors solutions (A, B) or (B, A) over the single vendor solutions (A, A) and (B, B) . In our illustration A and B are interchangeable without loss of generality. Hence, we focus on one representative comparison:

$$\begin{aligned}\Phi((A, B)) &> \Phi((A, A)) \\ \Leftrightarrow (\mu_{2,B} - \mu_{2,A}) - k_B - \alpha((\sigma_{2,B}^2 - \sigma_{2,A}^2) + 2(\sigma_{1,A}\sigma_{2,B}\rho_{1,A,2,B} - \sigma_{1,A}\sigma_{2,A}\rho_{1,A,2,A})) &> 0\end{aligned}$$

Since in this example the first subproject is conducted by A in either option, the expected net present value of the second subproject might be critical for either a single vendor or multiple vendor strategy. It therefore is an advantage for (A, B) if $\mu_{2,B} > \mu_{2,A}$ and a disadvantage if $\mu_{2,B} < \mu_{2,A}$. Choosing (A, B) instead of (A, A) causes additional transaction costs k_B which is a downside of multisourcing.

Risk has to be examined in more detail: First, we look at the respective values of the variance as our measure of risk. $\sigma_{2,B}^2 < \sigma_{2,A}^2$ (B delivering the second subproject at a lower risk than A) is an advantage for (A, B) , analogous $\sigma_{2,B}^2 > \sigma_{2,A}^2$ is a disadvantage. Second, we examine the dependencies between the two subprojects depicted by the respective covariances $\sigma_{1,A}\sigma_{2,B}\rho_{1,A,2,B}$ and $\sigma_{1,A}\sigma_{2,A}\rho_{1,A,2,A}$.

Depending on the values of the standard deviations $\sigma_{2,B}$, $\sigma_{2,A}$ and the correlation coefficients $\rho_{1,A,2,B}$, $\rho_{1,A,2,A}$, those can be an advantage or disadvantage for (A, B) .

In reality, however, we will find that subprojects conducted by different vendors feature lower dependencies than subprojects conducted by the same vendor. This can be explained by vendor specific risk, e.g. unexpected low performance of a single vendor. Consequently, in a real-world setting we can expect that $\rho_{1,A,2,B} < \rho_{1,A,2,A}$. As long as this effect is not outweighed by a high standard deviation $\sigma_{2,B}$ compared to a lower $\sigma_{2,A}$, multisourcing bears the opportunity of risk diversification.

Altogether, we can state that the decision on multisourcing heavily depends on the respective values of the different variables. Especially risk can be an aspect in favor of or against multisourcing and neglecting risk can lead to a different decision outcome. In the following sections we analyze in more detail what consequences neglecting risk might lead to.

II.3.4.2 Evaluation based on a Monte Carlo Simulation

The problem at hand is very complex, as it requires a full enumeration for each project setting to derive the respective optimal vendor selection. Consequently, a sensitivity analysis cannot be conducted analytically for large project settings. We chose the Monte Carlo method as it permits the processing of complex problems within reasonable time and derives results based on the law of large numbers. Using a Monte Carlo simulation, we can treat the full enumeration as a black box and implement a sensitivity analysis by running the simulation with original and slightly adapted input parameters. Lacking real world data, we furthermore need to create those project settings assuming realistic distributions for our input parameters. This way, we are able to confirm effects identified during the analytical evaluation for a very small project setting or to identify effects which occur in large project settings only.

We generated 1000 different project settings. Each project consists of 6 subprojects each of which is conducted by one of 7 vendors. The following table 1 shows the respective ranges of the input data for the simulation of a single project setting. In this context, the term „vendor specificity“ means that for each subproject a basic expected net present value and standard deviation were created randomly within the given range and then varied for each individual vendor. For reasons of simplicity we speak of μ , σ , ρ , and k in the following, meaning all expected values, standard deviations, correlations, and transaction costs, respectively, for all subprojects and vendors.

Table 1. Monte Carlo input data

| | Range | Distribution |
|---|---|-------------------------|
| Expected net present value of each subproject (μ) | 10,000 – 100,000 | equal |
| vendor specificity | | gaussian ($\pm 10\%$) |
| Standard deviation of each subproject (σ) | 0 – 20% of subproject's net present value | equal |
| vendor specificity | | gaussian ($\pm 10\%$) |
| Transaction costs of each vendor (k) | 20,000 (mean) | gaussian ($\pm 25\%$) |
| Parameter of risk aversion (α) | $5 \cdot 10^{-5} - 15 \cdot 10^{-5}$ | equal |
| Correlations (ρ) for subprojects outsourced to the same vendor | 0.0 – 0.8 | gaussian (mean: 0.4) |
| Correlations (ρ) for subprojects outsourced to different vendors | 0.0 – 0.8 | gaussian (mean: 0.2) |

For each project setting, we identified the vendor selection \vec{v} that maximizes $\Phi(\vec{v})$, the value of $\Phi(\vec{v})$, and how many different vendors are components of the vendor portfolio described by \vec{v} .

To conduct the sensitivity analysis, we furthermore generated comparative scenarios by varying the input parameters listed below individually by -50%, -25%, -5%, -1%, +1%, +5%, +25%, and +50%.

- Parameter of risk aversion (α)
- Expected net present values (μ)
- Standard deviations (σ)
- Correlations (ρ)
- Transaction costs (k)

Defining \vec{v}' as the decision vector of a comparative scenario and Φ' as value of the comparative objective function, we identified for each project, which vendor selection \vec{v}' maximizes $\Phi'(\vec{v}')$. For comparison we furthermore evaluated, in how many positions the comparative vendor selection \vec{v}'

differs from the optimal vendor selection \vec{v} and by what amount the initial objective function differs when inserting the initial and comparative selection respectively: $\Phi(\vec{v}) - \Phi(\vec{v}')$, i.e. we determined the monetary damage the variation of the input parameter causes in reference to the initial objective function.

The damage can be interpreted as follows: With Φ based upon „accurate“ values and Φ' based upon an erroneous estimation, the damage measures the difference of the value of the initial objective function Φ with different input vectors: on the one hand the optimal selection \vec{v} and on the other the „wrong“ selection \vec{v}' . As $\Phi(\vec{v})$ is optimal and as $\Phi(\vec{v}')$ is suboptimal, we can conclude that the damage is always greater than or equal to zero. Interpreting $\Phi(\vec{v})$ and $\Phi(\vec{v}')$ as certainty equivalents (amounts of money), the damage can be interpreted as an amount of money, too.

II.3.4.3 Model Robustness

Appendix I contains the list of average results derived from 1000 Monte Carlo runs. It shows the respective input parameter that is varied to generate the comparative scenario (column 1) and the respective rates of change (column 2). The third column lists the average number of differences in the portfolio composition, i.e. the different vendor selection of the initial and the comparative scenarios. The fourth column contains the average absolute damage concerning the risk adjusted net present value of the project resulting from the variation. In order to provide a more generally interpretable measure of the consequences of the variation, the fifth column lists the relative damage based upon the average project net present value of 3,153,415.13 which was calculated from all project settings generated by the Monte Carlo simulation. The analysis of the data implies four interesting findings:

1. According to a Wilcoxon signed-rank test, there is a statistically significant difference in the medians of $\Phi(\vec{v})$ and $\Phi(\vec{v}')$ despite one exception (transaction costs varied by +1%, fourth from last row). This means, that for all other parameters even an erroneous estimation of only $\pm 1\%$ leads to a statistical significant damage.
2. Surprisingly, the damage is very small: Even with an estimation error of +50%, for the standard deviation the relative damage stays below 5%. For all other parameters estimation errors between $\pm 50\%$ lead to relative damages below 1.5%.
3. Despite the above mentioned low average and relative damage, the portfolio composition shows remarkable changes. The composition of the vendor portfolio alters up to an average of 2,57 positions (standard deviations varied by -50%, row 17) for a certain variation, due to the misestimation.
4. Overestimating the input parameters of the objective function causes less damage concerning the risk adjusted net present value of the project than underestimating them. Concerning research question 2, this is especially interesting for the parameters modeling risk (α , σ , and ϱ). Obviously, it causes less damage to be too cautious in risk assessment, than to be too negligent.

In summary it can be stated, that assessing risk not only is of utmost importance, but also the model elaborated above is very robust in regard to estimation errors.

II.3.5 On the Importance of Risk Assessment

Neglecting risk, a decision maker decides on a multi-vendor IT outsourcing portfolio only by evaluating whether increased expected net present values due to specialization of certain providers are outweighed by the respective transaction costs. In our model this exact situation can be produced by setting α and/or σ equal to zero (zeroizing the parameter of risk aversion α and all standard deviations σ has the exact same effect as they are multiplicatively linked).

The robustness of the model elaborated above, exposed a limited sensitivity regarding the variation of individual parameters even by $\pm 50\%$. This finding might lead to the presumption, that neglecting risk (i.e. varying α and/or σ by -100%) would also lead to minor damage concerning the risk adjusted net present value of the project.

To scrutinize this presumption, we evaluated a comparative scenario setting the parameter of risk aversion α equal to zero. Therewith, risk is not taken into account when indentifying the optimal vendor portfolio selection of a project. We get the values as depicted in table 2.

Table 2. Consequences of neglecting risk

| | Estimation error | Average # of differences in vendor selections | Average damage | Relative damage |
|---|------------------|---|----------------|-----------------|
| Parameter of risk aversion (α) | -100% | 3.844 | 1323578.528 | 41.973% |

According to table 2, the damage from neglecting risk exceeds the damage from overestimating or underestimating risk tremendously. Considering the comparative scenarios listed in appendix I, underestimating the standard deviations by 50% has the highest impact. It leads to an average of 2.57 subprojects assigned to different vendors and to a relative damage of less than 5%. Neglecting risk leads to an average of nearly 4 subprojects ($\frac{2}{3}$ of the entire project's components) assigned to different vendors and to a relative damage of more than 40%.

This investigation also suggests the presumption that there is a positive correlation between the number of differences in vendor selection and the resulting damage. While this might seem trivial on first sight, it is not necessarily a predicate of portfolio selection. Completely different portfolios can still feature similar risk-adjusted net present values. We tested our dataset for this correlation and found that the damage when neglecting risk is indeed positively correlated to the number of differences in portfolio selection with a correlation coefficient of 0.397 (significant at the 0.01 level).

As a consequence we can state that risk assessment based upon an erroneous estimation still leads to much better results than neglecting risk completely whereupon the resulting damage is substantial. We would therefore strongly recommend practitioners to integrate the assessment of risk and dependencies into their vendor selection processes. As a first step, our model could be used and adapted for decision support.

II.3.6 Practical Implications, Limitations and Conclusion

Today's businesses usually omit a quantitative risk assessment when deciding on multi-vendor IT outsourcing. Some do extend their focus from a pure cash-flow oriented view to a more generic one and integrate risk and dependencies into their decisions. Nevertheless, these approaches are often pragmatic and methodically weak. The vision of a value adding quantitative IT portfolio management in the context of multi-vendor IT outsourcing requires methodically rigorous models that deliver initial reasonable results, although they might not be suitable to be applied in practice without some company-specific adjustments.

Although it bears great potential of economic improvement, still little quantitative research exists in the field of multi-vendor IT outsourcing. Therefore, this paper not only presents an analytical model to allocate vendors to subprojects in an optimal way, accounting for expected net present values, risk, transaction costs, and dependencies between subprojects conducted by either the same or different vendors (research question 1). But also, this contribution illustrates the importance of risk assessment within multi-vendor IT outsourcing decisions using a Monte Carlo simulation. The model is quite robust in terms of estimation errors. It shows that optimizing the allocation of vendors and neglecting risk completely causes significantly higher damage (research question 2). Moreover, the approach shows that overestimating the model's parameters seems to have a smaller impact than underestimating them.

Altogether, we can derive the following implications for management from this paper:

- a) When allocating multiple vendors to a project, it makes good economic sense to include a risk evaluation into the decision process.
- b) An erroneous estimation of risk and the corresponding interdependencies is might still be better than neglecting risk completely.
- c) Make conservative estimations regarding risk: Overestimating standard deviations and correlations causes less damage than underestimating them.

One aspect which is not covered by this paper is the following: The main reason for omitting a profound risk assessment in today's companies is most likely the fact, that risk assessment is a complex task which incurs a decent amount of time and money itself. This raises further research questions which we might address in future contributions, e.g. questions about an economical optimal degree of estimation accuracy in risk assessment. Nevertheless, according to our management implication b) it is economically reasonable to include at least some sort of risk assessment in the evaluation process of multi-vendor outsourcing.

Considering limitations of our findings, one has to mention that the model's inherent interpretation of risk is rather abstract. That means our model is limited to deal with quantifiable and attributable components of risk, only. When applying our model, risk factors that are hard to quantify (e.g. cultural aspects) have to be either neglected or converted into quantitative figures by using appropriate methods. Furthermore, our model pictures dependencies within one project only. The development of an integrated model considering the existing outsourcing vendor and project portfolios as well as the decision on additional vendors and projects might be of great significance to practitioners as well as to researchers.

Although the model pictures reality in a slightly constrained way, it provides a basis for firms to plan and improve their multi-vendor outsourcing strategies. Moreover, it is a theoretically sound economical approach which allows further development and delivers insights in the assessment of risk.

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II.3.8 Appendix I

| 1. | 2.Estimation error | 3.Average # of differences in vendor selections | 4.Average damage | 5.Relative damage |
|---|--------------------|---|------------------|-------------------|
| 6.Parameter of risk aversion (α) | 7.-50% | 8.1.556 | 9.32949.93 | 10.1.045% |
| | 11.-25% | 12.0.676 | 13.4454.25 | 14.0.141% |
| | 15.-5% | 16.0.125 | 17.164.75 | 18.0.005% |
| | 19.-1% | 20.0.025 | 21.7.22 | 22.0.000% |
| | 23.+1% | 24.0.03 | 25.6.99 | 26.0.000% |
| | 27.+5% | 28.0.104 | 29.115.23 | 30.0.004% |
| | 31.+25% | 32.0.531 | 33.2510.68 | 34.0.080% |
| | 35.+50% | 36.0.888 | 37.7414.73 | 38.0.235% |
| 39.Expected net present values (μ) | 40.-50% | 41.1.315 | 42.18478.94 | 43.0.586% |
| | 44.-25% | 45.0.658 | 46.3974.87 | 47.0.126% |
| | 48.-5% | 49.0.133 | 50.173.99 | 51.0.006% |
| | 52.-1% | 53.0.029 | 54.5.84 | 55.0.000% |
| | 56.+1% | 57.0.024 | 58.7.00 | 59.0.000% |
| | 60.+5% | 61.0.122 | 62.134.30 | 63.0.004% |
| | 64.+25% | 65.0.532 | 66.2623.37 | 67.0.083% |
| | 68.+50% | 69.0.934 | 70.9814.07 | 71.0.311% |
| 72.Standard deviations (σ) | 73.-50% | 74.2.57 | 75.152203.91 | 76.4.827% |
| | 77.-25% | 78.1.301 | 79.21928.34 | 80.0.695% |
| | 81.-5% | 82.0.251 | 83.580.96 | 84.0.018% |
| | 85.-1% | 86.0.039 | 87.16.14 | 88.0.001% |
| | 89.+1% | 90.0.042 | 91.12.10 | 92.0.000% |
| | 93.+5% | 94.0.259 | 95.501.51 | 96.0.016% |

| | | | | |
|---|-----------|-----------|--------------|------------|
| | 97.+25% | 98.0.924 | 99.8211.75 | 100.0.260% |
| | 101.+50% | 102.1.498 | 103.24762.58 | 104.0.785% |
| 105. Correlations (ρ) | 106.-50% | 107.1.382 | 108.35792.81 | 109.1.135% |
| | 110.-25% | 111.0.665 | 112.6136.45 | 113.0.195% |
| | 114.-5% | 115.0.096 | 116.130.15 | 117.0.004% |
| | 118.-1% | 119.0.026 | 120.7.96 | 121.0.000% |
| | 122.+1% | 123.0.023 | 124.3.64 | 125.0.000% |
| | 126.+5% | 127.0.105 | 128.151.21 | 129.0.005% |
| | 130.+25% | 131.0.538 | 132.3566.84 | 133.0.113% |
| | 134.+50% | 135.0.962 | 136.11266.05 | 137.0.357% |
| 138. Transaction costs (k) | 139.-50% | 140.0.437 | 141.1934.62 | 142.0.061% |
| | 143.-25% | 144.0.198 | 145.418.17 | 146.0.013% |
| | 147.-5% | 148.0.047 | 149.21.07 | 150.0.001% |
| | 151.-1%* | 152.0.006 | 153.0.65 | 154.0.000% |
| | 155.+1%** | 156.0.001 | 157.0.07 | 158.0.000% |
| | 159.+5% | 160.0.029 | 161.8.17 | 162.0.000% |
| | 163.+25% | 164.0.175 | 165.342.30 | 166.0.011% |
| | 167.+50% | 168.0.307 | 169.1079.04 | 170.0.034% |
| 171.* Median of Φ is different with a significance at the 0.05 level (2-tailed). | | | | |
| 172.** Median of Φ is different with a significance of 0.317 (2-tailed). | | | | |
| 173.All other medians of Φ are different with a significance at the 0.01 level (2-tailed). | | | | |

II.4 IT-Multisourcingentscheidungen mit Methoden des Portfoliomanagements

| | |
|---------------|--|
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Immer mehr Unternehmen erweitern ihre IT-Sourcingstrategien von Singlesourcing zu Multisourcing, um mit Hilfe einer optimierten Kombination von Anbietern ihre Unternehmensziele besser zu erreichen. Dieser Beitrag überträgt existierende Methoden aus dem Finanzmanagement auf die IT-Multisourcing-Problemstellung, um sich der Frage anzunähern, welche Sourcinganbieter zur Durchführung eines IT-Projekts herangezogen werden sollen. Somit ergänzt das Vorgehen das bestehende IT-Projektmanagement um einen quantitativen Aspekt, der zusätzlich zur qualitativen Analyse herangezogen werden kann.

Stichwörter: Multisourcing, Outsourcing, Outsourcinganbieter, IT-Projektmanagement, IT-Portfoliomanagement, Investitionsplanung

II.4.1 IT-Sourcing vor dem Hintergrund einer wertorientierten Unternehmensführung

IT-Outsourcing wird definiert als die Auslagerung von Tätigkeiten der IT-Abteilung an einen externen Dienstleister, der diese gegen Bezahlung durchführt. Viele Unternehmen verfolgen IT-Outsourcingstrategien, um Kosten und/oder Risiken ihrer Geschäftsprozesse zu mindern. Der erhöhte Konkurrenzdruck erfordert in vielen Branchen eine strenge Kostenkontrolle. Somit wuchs der Markt für Sourcingdienstleistungen in der Vergangenheit erheblich an und wird aller Voraussicht nach auch in Zukunft die bisherigen Wachstumsraten übertreffen. Treiber dieser Entwicklung sind unter anderem IT-Sourcinganbieter, die sich spezialisieren und dadurch immer wettbewerbsfähiger werden [Lacity et al. 2009]. Dies ermöglicht vielen Firmen noch profitablere Sourcingverträge abzuschließen, da sich die Anbieter als Experten in ihrem Gebiet beweisen.

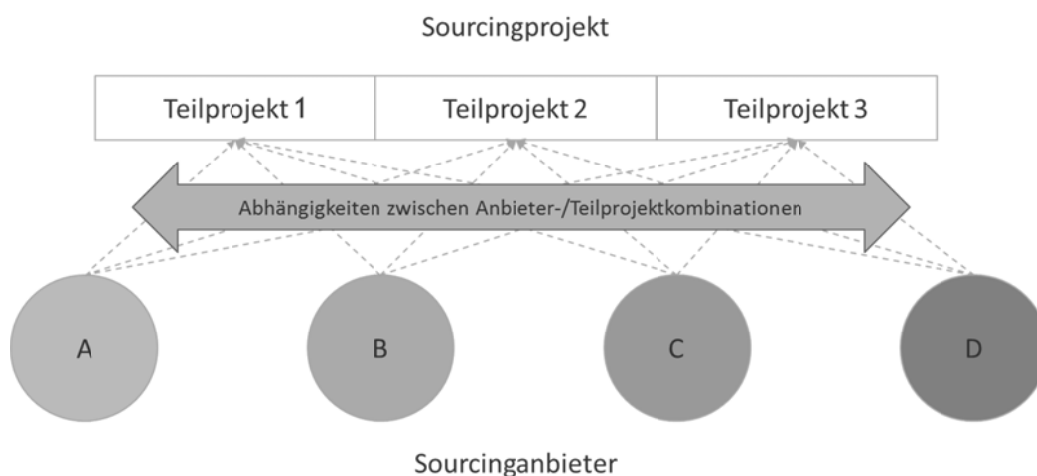
Allerdings fällt es vielen Unternehmen schwer Sourcingprojekte zielgerichtet, im Sinne der wertorientierten Unternehmensführung, umzusetzen, da Projektbewertungsprozesse nicht immer definiert und dokumentiert sind. Vor diesem Hintergrund scheint es nützlich, den Unternehmen ein Vorgehen an die Hand zu geben, mit dessen Hilfe IT-Sourcingentscheidungen - am Gesamtziel Unternehmenswertsteigerung ausgerichtet - unterstützt werden können.

Im deutschsprachigen Raum wird die Auslagerung von Tätigkeiten der IT-Abteilung an externe Dienstleister seit den 1960er Jahren wissenschaftlich diskutiert. Der Begriff ‚Datenverarbeitung außer Haus‘ wurde von Heinrich [1965] geprägt. Der erste große IT-Outsourcing-Megadeal im Jahre 1989 von Eastman Kodak gilt als Impulsgeber für den heute immer noch anhaltenden Trend. Da Outsourcing-Megadeals mit hohen Abhängigkeiten von einem einzelnen Anbieter verbunden waren, entwickelte sich über die Zeit das so genannte selektive Outsourcing kleinerer Leistungspakete. Vor diesem Hintergrund wurde der Begriff „Rightsourcing“ geprägt, der ein gewissenhaftes Risikomanagement mit Betrachtung der Abhängigkeiten zwischen den verschiedenen Sourcinganbietern beschreibt. Zum Beispiel evaluiert die Firma Grand Metropolitan aus der Lebensmittelindustrie nicht nur die spezifischen Funktionalitäten, die zu einem Sourcinganbieter ausgelagert werden, sondern auch die Anbieter selbst. Dies führt zu einer Strategie, die neben selektivem Sourcing auch das Sourcing mit verschiedenen Anbietern, das so genannte Multisourcing, beinhaltet. Dadurch wird die Abhängigkeit von einem Anbieter reduziert, der Kunde erhält somit mehr Verhandlungsmacht gegenüber den verschiedenen Sourcinganbietern. Kostenvorteile können verstärkt ausgenutzt werden und durch die Spezialisierung und Professionalisierung der Projektpartner erhöht sich deren Leistungsfähigkeit. Allerdings muss der dadurch erhöhte Kommunikations- und Koordinationsaufwand ebenfalls berücksichtigt werden. Da mehrere Sourcinganbieter Konkurrenten und Teamkollegen zur gleichen Zeit sein können, sind diese abhängig von der jeweiligen Leistung des anderen. Diese Komplexität, die unter anderem durch die hohe Spezialisierung, technische Vielschichtigkeit und bestehende Abhängigkeiten entsteht, stellt den Entscheider vor ein nur schwer durchschaubares Entscheidungsproblem. Um solche Probleme transparent zu machen und Entscheidungen zu unterstützen, die dem Ziel der wertorientierten Unternehmensführung gerecht werden, sind mathematische Modelle hilfreich, die diese Abhängigkeiten kalkulierbar machen, Risiken bewerten und finanzielle Kennzahlen in eine Entscheidungsgrundlage integrieren.

II.4.2 IT-Sourcingentscheidungen im Projektumfeld

Besonders bei IT-Projekten erfolgt die Leistungserbringung häufig durch mehrere externe Anbieter. Zum einen unterstützt der Projektcharakter die Auslagerbarkeit, da es sich bei Projekten um einmalige, innovative, zeitlich begrenzte Vorhaben mit einem definierten Ziel handelt. Zum anderen erfordert der Projektgegenstand Informationstechnologie, der sich meist durch Innovationskraft, hohe Komplexität und Risikoexposition auszeichnet, Know-how das in vielen Unternehmen intern nicht immer hinreichend vorhanden ist. Die Spezialisierung einzelner Sourcinganbieter ist in diesem Zusammenhang besonders nützlich. Abbildung 1 veranschaulicht vereinfacht die Problemstellung der Sourcingentscheidung im IT-Projektumfeld.

Abb. 1: Vereinfachte Darstellung einer Sourcingentscheidung



Die Implementierung einer quantitativen Bewertungsmethode für Multisourcing-Entscheidungen hat sich in der Praxis jedoch noch nicht etabliert. Meist wird lediglich anhand der Kosten entschieden, ohne die Risiken und vor allem die Abhängigkeiten zwischen Anbietern und Teilprojekten quantitativ mit in das Kalkül einzubeziehen. Ein Grund hierfür ist, dass die monetäre Bewertung zukünftiger, unsicherer und voneinander abhängiger Zahlungsströme vielschichtig ist. Daher erfordert deren Abschätzung entsprechendes Know-how und eine hohe Bereitschaft zur objektiven Beurteilung der Projekteigenschaften. Darüber hinaus basiert ein Großteil der Zahlungsströme auf schwer messbaren Faktoren wie beispielsweise Synergien oder Arbeitserleichterungen. Zudem sind Risiken und deren Auswirkungen meist nur schwer zu beurteilen. In der Literatur gibt es ebenfalls mehrere kostenfokussierte Verfahren zur Bewertung von Sourcingentscheidungen, meist jedoch ohne eine umfassende Betrachtung von Risiken und Abhängigkeiten. Einen Überblick über bestehende Ansätze geben Dibbern et al. [2004]. Ein ökonomisch fundiertes Modell zur Bewertung von Multisourcing-Entscheidungen unter Berücksichtigung von Kosten, Risiken und Abhängigkeiten wurde von Fridgen und Mueller [2011] entwickelt. Aufgrund der hohen Komplexität ist dieser allerdings nur schwer in der Praxis umsetzbar. Daher soll nun die Anwendbarkeit der Methode verbessert und Hilfestellungen für

deren Einsatz im Unternehmensumfeld geleistet werden. Um die Schwierigkeit einer Sourcingentscheidung abzumildern und dennoch eine ökonomisch fundierte Entscheidung unterstützen zu können, werden - angelehnt an bestehende Portfoliomanagementmethoden - Anforderungen an eine Methode zur Bewertung von IT-Sourcingentscheidungen abgeleitet.

II.4.3 Anforderungen an eine Bewertungsmethode für IT-Sourcingentscheidungen

Berücksichtigung von Risiko

IT-Sourcingvorhaben unterliegen bestimmten Risiken, die sich nach Verhoef [2005] in Budgetüberschreitungen, Zeitverzögerungen und der Nichterfüllung von fachlichen Anforderungen auswirken. Daneben bestehen Projektrisiken, die sich aus dem Überschreiten von gesetzlichen, vertraglichen oder sozialen Normen ergeben. Die beschriebenen Effekte führen zu möglichen Schwankungen der Zahlungsströme, die entweder positiv oder negativ ausfallen können. Diese sollten in die Bewertung von Entscheidungsalternativen mit einfließen.

Berücksichtigung von Abhängigkeiten

Da die verschiedenen Teilprojekte auf den gleichen Pool an Ressourcen (Mitarbeiter und deren Kompetenzen, Infrastruktur, Budget etc.) zugreifen, entstehen Abhängigkeiten struktureller oder organisatorischer Art. Strukturelle Abhängigkeiten treten auf, wenn verschiedene Teilprojekte auf dieselben Prozesse, Anwendungssysteme oder Infrastruktur zugreifen, d.h. die Beschaffenheit von Systemen hat Auswirkungen auf den Projektverlauf. Wenn zum Beispiel in mehreren Teilprojekten Anwendungen entwickelt werden, die auf derselben Systemsoftware laufen, welche sich als fehleranfällig oder schlecht dokumentiert herausstellt, so kann dies die entsprechenden Teilprojekte gleichermaßen negativ beeinflussen. Organisatorische Abhängigkeiten entstehen durch Konkurrenz um dieselben Ressourcen, d.h. die Art der Durchführung hat Auswirkungen auf den Projektverlauf. Wenn zum Beispiel besondere Projektmanagementkompetenzen in mehr als einem Teilprojekt verlangt werden, kann das negative Auswirkungen mit sich bringen, falls die Anforderungen der Projekte die Kapazitäten übersteigen. Die genannten Abhängigkeiten zwischen Teilprojekten müssen in eine integrierte Bewertung von IT-Sourcingentscheidungen miteinbezogen werden. [Zimmermann 2008]

Monetäre Bewertung

Um Entscheidungsunterstützung bezüglich des Sourcings eines Projekts bzw. dessen Teilprojekten zu ermöglichen, muss der Beitrag jedes (Teil-)Projekts zum Unternehmenswert gemessen werden. Das bedeutet, dass Einzahlungen, Auszahlungen, Risiken und Abhängigkeiten geschätzt und quantitativ abgebildet werden müssen, um damit die Vergleichbarkeit von Teilprojekten in Abhängigkeit vom Anbieter sowie die Aggregation von mehreren Teilprojekten zu ermöglichen.

Praktische Umsetzbarkeit der Bewertungsmethode

Die Methode muss zudem praktisch anwendbar sein, d.h. es sollte Nutzerfreundlichkeit sichergestellt werden und sie sollte mit vertretbarem Aufwand angewandt werden können, um im dynamischen

Managementumfeld Entscheidungsunterstützung zu leisten. Nur wenn der Ansatz auch entsprechend in der Praxis Berücksichtigung finden kann, ist dessen Entwicklung aus Unternehmenssicht vertretbar. Zum Beispiel sollten im besten Falle schon während der Vertragsverhandlungen verschiedene Szenarien abgebildet und bewertet werden können, um die optimale Allokation von Sourcingpartnern zu identifizieren.

II.4.4 Unterstützung von IT-Sourcingentscheidungen mit Methoden des Portfoliomanagements

Um die Auslagerung eines (Teil-)Projekts zu bewerten, muss der Entscheider verschiedene zur Verfügung stehende Anbieter identifizieren und deren jeweilige Charakteristika evaluieren. Eine bewertungsunabhängige Größe zur Messung des Beitrags zum Unternehmenswert eines IT-Projekts im Allgemeinen und damit auch eines IT-Sourcingprojekts im Speziellen ist der Discounted Cash-Flow (DCF). Dabei werden zukünftige Einzahlungen abzüglich der Auszahlungen pro Periode betrachtet und auf den Zeitpunkt der Entscheidung abgezinst. Da weder Cash-Flows noch die DCFs mit Sicherheit bestimmt werden können, also risikobehaftet sind und nach oben sowie nach unten abweichen können, werden letztere als normalverteilte Zufallsvariablen angenommen [Wehrmann et al. 2006]. Deren Erwartungswert beschreibt die Größe, die der DCF im Mittel annehmen wird und wird durch den Parameter μ abgebildet. Je größer die mit einem (Teil-)Projekt verbundene Unsicherheit desto größer ist die Abweichung vom erwarteten DCF, mit der gerechnet werden muss. Zur Messung dieser Abweichung wird ein Streuungsmaß herangezogen, d.h. als Maßgröße für das Risiko der als normalverteilt angesehenen Cash-Flows wird die Standardabweichung verwendet, die durch den Parameter σ dargestellt wird.

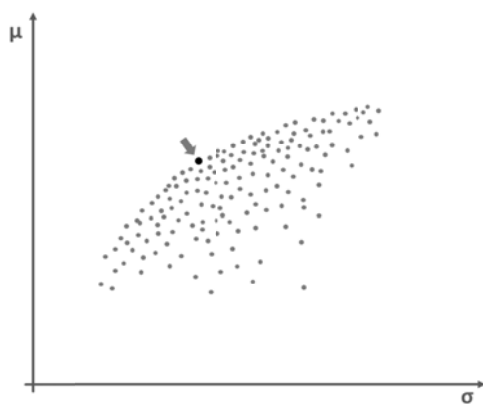
Um nun aus mehreren Anbietern die optimale Allokation auswählen zu können, erfolgt die aggregierte Betrachtung aller möglichen Anbieter-/Teilprojektkombinationen mit Hilfe eines in der Kapitalmarkttheorie gängigen Verfahrens, das im Folgenden vorgestellt wird.

Die Theorie zur Portfolioselektion wurde 1952 von Harry M. Markowitz entwickelt. Sie enthält ein formales Entscheidungsmodell, mit dessen Hilfe ermittelt werden kann, welche Wertpapiere zu welchen Anteilen in ein Portfolio aufgenommen werden sollen und welchen Einfluss Diversifikationseffekte auf die Entscheidung haben. Die Kombination von mehreren risikobehafteten Vermögensgegenständen in einem Portfolio kann dazu führen, dass das Risiko im Portfolio bei gleichem Ertrag geringer ist als die kumulierten Risiken der einzelnen Elemente. Diesen Effekt nennt man Risikostreuung oder Diversifikation. Ziel der Portfolioselektion ist es, die Zusammensetzung von Anlagen zu bestimmen, die eine effiziente Rendite-/Risikokombination bilden. [Markowitz 1952] Auch in anderen Disziplinen gibt es Verfahren, die den Diversifikationseffekt entsprechend berücksichtigen. Beispiele hierfür sind das Management von Produkt- und/oder Kundenportfolios. Auch zwischen Teilprojekten mit unterschiedlichem Sourcing können Risikodiversifikationseffekte realisiert werden. Lässt zum Beispiel ein Entscheider ein IT-Projekt von einem einzigen Anbieter durchführen, ist er von diesem zu 100% abhängig. Wenn der Anbieter nun Leistungen in schlechter Qualität oder verzögert liefert, was zu höheren Auszahlungen führt, ist das gesamte Projekt betroffen. Wird jedoch das Projekt von mehreren Anbietern durchgeführt, sind, auch wenn bei einem der Anbieter höhere Auszahlungen

anfallen, die anderen Teilprojekte nicht betroffen. Die Vergabe der Teilprojekte an mehrere Anbieter birgt also die Chance, dass sich das finanzielle Risiko des Gesamtprojekts reduziert. Verfügbarkeitsrisiken, also Ausfälle von Teilprojekten, werden hierbei jedoch nicht betrachtet. Der Effekt der Risikoreduktion wird durch den gegenläufigen Effekt des höheren Koordinationsaufwands bei mehreren Anbietern verringert. Auf die Modellierung dieses Sachverhalts wird an dieser Stelle aus Gründen der Übersichtlichkeit verzichtet. In Fridgen und Mueller [2011] ist diese Erweiterung dargestellt.

Um nun das optimale Anbieterportfolio zu bestimmen, werden alle möglichen Anbieter-/Teilprojektkombinationen durch eine Schätzung bestimmt und die jeweilige Kombination von erwartetem Teilprojekt-DCF und zugehörigem Risiko als Punktwolke in Abbildung 2 veranschaulicht. Der obere Rand der Punktwolke wird als effizienter Rand bezeichnet. Auf ihm liegen alle Portfoliokombinationen, die von keiner anderen Kombination dominiert werden. D.h. es gibt kein Portfolio, das entweder bei gleichem Risiko einen höheren Erwartungswert oder bei gleichem Erwartungswert ein geringeres Risiko besitzt. Die Steigung des effizienten Randes bildet ab, dass für effiziente Portfolios ein höherer Erwartungswert der DCFs auch mit einem höheren Risiko verbunden ist. Da allerdings aufgrund der Diversifikationseffekte das Verbundrisiko im Portfolio üblicherweise geringer ist als die Summe der Einzelrisiken, verläuft er konkav.

Abb. 2: Identifikation des optimalen Projektwerts aus allen möglichen Teilprojekt-/Anbieterkombinationen



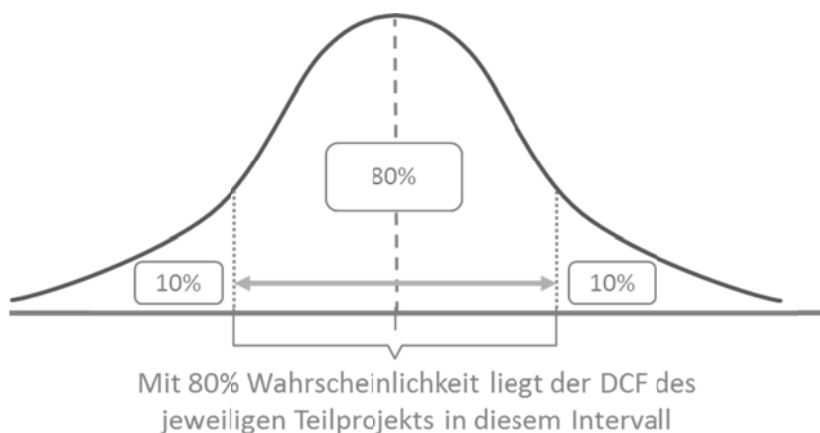
Aus der Menge der effizienten Teilprojekt-/Anbieterkombinationen kann mit Hilfe einer Bewertungsfunktion das optimale Portfolio bestimmt werden [Wehrmann & Zimmermann 2005]. Dazu wird vom Portfolioerwartungswert der normalverteilten DCFs eine Risikoprämie abgezogen, die sich aus der Portfoliovarianz σ^2 multipliziert mit der individuellen Risikoeinstellung α des Entscheidungsträgers ergibt. Die Portfoliovarianz wird aus der Summe der Standardabweichungen der DCFs der jeweiligen relevanten Teilprojekt-Anbieterkombinationen, die jeweils miteinander sowie mit dem entsprechenden Korrelationskoeffizienten multipliziert werden, gebildet. Ist der Entscheider risikoneutral, nimmt die Risikoeinstellung α den Wert null an und das Risiko beeinflusst die Entscheidung nicht. Bei einem risikoaversen Entscheider nimmt α einen Wert größer null an. Die Risikoeinstellung des Entscheiders, in diesem Falle des gesamten Unternehmens, sollte von der

Geschäftsleitung festgelegt werden. Die Bildung einer solchen Bewertungsfunktion entspricht dem entscheidungstheoretisch fundierten Vorgehen [vgl. Bamberg et al. 2006], das wegen seiner Interpretierbarkeit und analytisch flexiblen Verwendbarkeit im betriebswirtschaftlichen Kontext häufig angewandt wird. Die Bewertungsfunktion hat für jedes Teilprojekt-/Anbieterportfolio folgende Struktur: $\Phi = \mu - \frac{1}{2}\alpha\sigma^2$. Für zwei und mehr Anbieter mit einer Zuordnung zu beliebig vielen Teilprojekten kann ein Vektor für die Indikation der Portfoliozusammensetzung in die Zielfunktion eingesetzt werden. Eine mögliche Lösung solcher Probleme ist in Fridgen und Mueller [2011] zu finden.

II.4.5 Hilfestellungen für den Einsatz in der Praxis

Das oben beschriebene Vorgehen zeigt, dass mit Hilfe von Portfoliomanagementmethoden aus dem Bereich der Kapitalmarkttheorie die Beantwortung der Frage nach der optimalen Sourcingentscheidung unterstützt werden kann. Obwohl die zugrundeliegende Methodik in der Wissenschaft im Bereich des IT-Portfoliomanagements bereits etabliert ist und auch bereits in der Praxis angewandt wird, bestehen bezüglich der Schätzung von Parametern wie Erwartungswert, Standardabweichung, Korrelationen und Risikoaversion merklich Vorbehalte. Da die Bestimmung dieser Parameter allerdings für die Anwendung der Bewertungsmethode von großer Bedeutung ist, werden im Folgenden konkrete Maßnahmen dargestellt, die deren Bestimmung deutlich vereinfachen.

Um die Unsicherheit der Zahlungsströme in einem IT-Sourcingprojekt zu berücksichtigen, werden Erwartungswert und Standardabweichung der Cash-Flows erhoben, indem eine Schätzung der Parameter durchgeführt wird. Um das zusätzliche Risiko der Fehleinschätzung möglichst gering zu halten, kann hier ein vereinfachendes intervallbasiertes Verfahren angewandt werden. Dabei soll der Schätzer, in der Regel ein Projektmitarbeiter, ein symmetrisches Intervall angeben, innerhalb dessen der DCF des jeweiligen Teilprojekts mit einer Wahrscheinlichkeit von 80% liegen wird (siehe Abbildung 3), d.h. die Wahrscheinlichkeit für eine Überschreitung bzw. Unterschreitung der oberen bzw. unteren Intervallgrenze liegt bei jeweils 10%. Indem der Entscheider das Intervall des geschätzten Werts mit einer bestimmten Wahrscheinlichkeit angibt, kann daraus mathematisch (unter der Annahme, dass die Projektwerte normalverteilt sind) der Erwartungswert und die Standardabweichung des entsprechenden Werts ermittelt werden. Zum Beispiel gibt der Schätzer an, dass sich die Auszahlungen für die Oberflächengestaltung durch einen bestimmten Anbieter mit einer Wahrscheinlichkeit von 80% im Intervall [170;190] bewegt. Dieses Verfahren, das eine nachvollziehbare und einfache Bewertung der Teilprojekte ermöglicht, findet auch im Bereich der Behavioral Economics Anwendung.

Abb. 3: Intervallschätzung zur Bestimmung von Erwartungswert und Standardabweichung

Die Identifikation der Korrelationskoeffizienten zwischen je zwei Teilprojekten und Anbietern ist ebenfalls eine komplexe Aufgabe, da eine hohe Anzahl von Parametern geschätzt werden muss und Projektmitarbeiter den Zusammenhang der Werte nur sehr schwer nachvollziehen können. Folgendes vereinfachende Verfahren kann in der Praxis deshalb zur Anwendung gebracht werden: Es wird ein Standardwert definiert, der besagt, dass alle Teilprojekte und Anbieter positiv korreliert sind. Diese Voreinstellung ist nachvollziehbar, da alle Teilprojekte demselben Sourcingprojekt zugehörig sind und vom selben Unternehmen ausgelagert werden. Im Falle einer Abweichung muss lediglich für die entsprechenden Kombinationen von Teilprojekten und Anbietern diese Voreinstellung angepasst werden. Für den Entscheider kann diese Anpassung erleichtert werden, indem er eine von fünf Optionen in natürlicher Sprache auswählen kann und somit keine numerischen Werte für die Korrelationen eingeben muss.

Darüber hinaus ist für Praktiker das Konzept der Risikoaversion meist eher abstrakt. Mit Hilfe eines Fragebogens kann die Erhebung des Risikoaversionsparameters vereinfacht werden. Ein mögliches Verfahren zur Bestimmung der Risikoaversion ist strukturell verwandt mit dem oben beschriebenen intervallbasierten Ansatz der Behavioral Finance. Die Umfrage richtet sich an die Unternehmensführung, da der Risikoaversionsparameter für das gesamte Unternehmen bestimmt werden soll. Es werden der Unternehmensleitung in verschiedenen Szenarien mehrere Investitionsalternativen mit verschiedenen Ertrags- und Risikopositionen zur Auswahl vorgelegt. Anhand der jeweiligen Entscheidung kann für jedes Szenario rechnerisch der zugehörige Wert der Risikoaversion bestimmt werden. Der Mittelwert aus allen errechneten Werten gilt dann als Risikoaversionsparameter des Unternehmens.

II.4.6 Anwendungsbeispiel

Wir betrachten ein Industrieunternehmen, das ein Projekt zur Entwicklung einer Mobile App mit zwei Teilprojekten, Gestaltung der Oberfläche mit technischer Umsetzung der Funktionalität als Teilprojekt 1 und Anbindung an Backend Systeme über eine Gatewayverbindung als Teilprojekt 2, an bis zu zwei Sourcinganbieter auslagern möchte. Aufgrund der Unerfahrenheit des Unternehmens mit der Entwicklung von Mobile Apps und der hohen Komplexität der Anbindung an das bestehende System

besteht die Gefahr, dass die Auszahlungen für das Projekt die initiale Schätzung übertreffen könnten. Wenn nun beide Teilprojekte von einem Anbieter durchgeführt werden, ist die Gefahr hoch, dass beide Teilprojekte von Fehlern oder Verzögerungen, die höhere Auszahlungen bedingen, betroffen sind. Wenn nun aber die Teilprojekte von jeweils unterschiedlichen Anbietern durchgeführt werden, besteht die Möglichkeit, dass das jeweils andere Teilprojekt mit geringerer Wahrscheinlichkeit betroffen ist. Daher bietet die Aufteilung der Teilprojekte auf zwei Anbieter die Möglichkeit, das finanzielle Risiko des Gesamtprojekts zu verringern. (Ein Totalausfall eines der beiden Teilprojekte, der zum Scheitern des Gesamtprojekts führen würde, wird dabei nicht betrachtet.) Es ergeben sich also vier mögliche Szenarien der Durchführung: Ein Anbieter führt beide Teilprojekte durch (A;A), (B;B) oder ein Anbieter führt Teilprojekt 1 und der andere Anbieter führt Teilprojekt 2 durch (A;B), (B;A).

Zunächst wird vom Projektleiter des Industrieunternehmens das Intervall geschätzt, in dem sich der DCF (in TEUR) pro Teilprojekt und Anbieter mit einer Wahrscheinlichkeit von 80% bewegt. Grundlage seiner Schätzungen sind sowohl Informationen aus ersten Gesprächen mit beiden Serviceanbietern als auch Erfahrungswerte. Dabei betrachtet er sowohl erwartete Einzahlungen als auch Auszahlungen und gibt ein Intervall für den DCF pro Teilprojekt und Anbieter an (Tabelle 1, Zeile 3). Hieraus können die Erwartungswerte und Standardabweichungen für die jeweiligen Teilprojekte pro Anbieter errechnet werden (Tabelle 1, Zeile 4 und 5). Die vorliegenden Daten entstammen einem aktuellen Projekt eines führenden Industrieunternehmens der Baubranche. Zur Anonymisierung wurden die Daten transformiert.

Tab. 1: Intervallschätzung, Erwartungswerte und Standardabweichungen pro Teilprojekt

| Anbieter | A | | B | |
|-----------------------------|-----------|-----------|-----------|-----------|
| Teilprojekt | 1 | 2 | 1 | 2 |
| Intervallschätzung der DCFs | 170 - 190 | 105 - 120 | 175 - 180 | 110 - 135 |
| Erwartungswert der DCFs | 180,00 | 112,50 | 177,50 | 122,50 |
| Risiko der DCFs | 7,81 | 5,86 | 1,95 | 9,77 |

Um die individuelle Risikoeinstellung des Unternehmens zu berücksichtigen, wird bei der Unternehmensleitung der Risikoavversionsparameter über einen Fragebogen abgefragt. Im vorliegenden Beispiel ist die Risikoeinstellung des Unternehmens $\alpha=1$. Um die Verbundeffekte der Risiken darstellen zu können, werden die Korrelationen zwischen den Anbieter-/Teilprojektkombinationen abgefragt. Werden mehrere Teilprojekte vom selben Anbieter durchgeführt, ist in der Regel der Korrelationskoeffizient zwischen ihnen größer. Bei einer Durchführung der Teilprojekte von mehreren Anbietern ist der Korrelationskoeffizient, der den Risikodiversifikationseffekt abbildet, im Normalfall geringer. Daher wird von einer positiven Korrelation (0,8) zwischen unterschiedlichen Anbietern und Teilprojekten und von einer perfekt positiven

Korrelation (1) bei gleichen Anbietern für mehrere Teilprojekte als Standardwert ausgegangen. Anpassungen der vorgelegten Korrelationen sind im vorliegenden Beispiel nicht notwendig.

Mit Hilfe der oben beschriebenen Bewertungsfunktion können nun die Sourcingalternativen evaluiert werden. Daraus ergeben sich die in Tabelle 2 aggregierten Projektwerte für die jeweiligen Szenarien. Es ist zu sehen, dass das Szenario (B;A) den höchsten Zielfunktionswert aufweist. Das bedeutet, dass die Multisourcingstrategie mit Anbieter B für Teilprojekt 1 (Oberfläche mit Funktionalität) und Anbieter A für Teilprojekt 2 (Anbindung Backend Systeme) optimal ist. Das betrachtete Industrieunternehmen maximiert durch die Auswahl dieser Strategie seinen Unternehmenswert. Somit ergänzt dieses Vorgehen das Projektmanagement um einen quantitativen Aspekt und leistet Entscheidungsunterstützung bei der Identifikation einer optimalen Sourcingstrategie für IT-Projekte.

Tab. 2: Ermittelte Projektwerte der Sourcingalternativen

| Szenario | (A;A) | (B;B) | (A;B) | (B;A) |
|-------------|--------|--------|--------|--------|
| Projektwert | 199,04 | 231,34 | 163,26 | 261,77 |

Das vorgestellte Modell unterliegt jedoch gewissen Annahmen, die die Allgemeingültigkeit der abgeleiteten Aussagen einschränken. Zum einen wird von normalverteilten DCFs ausgegangen, um die Zahlungsströme der Teilprojekte mathematisch sauber zu einem Portfoliowert aggregieren zu können. Zum anderen wird eine beliebige Teilbarkeit von IT-Projekten unterstellt, die so in der Realität nur begrenzt umsetzbar ist. Darüber hinaus sind die Eigenschaften der jeweiligen Sourcinganbieter nur über die Schätzung der risikobehafteten DCFs abgebildet, wobei eine Quantifizierung der jeweiligen Nutzenkomponenten in der Praxis vermutlich schwierig bleiben wird. Aus Gründen der Übersichtlichkeit werden Transaktionskosten nicht berücksichtigt. Das Fallbeispiel veranschaulicht die Problemstellung mit zwei Teilprojekten und Anbietern, ist jedoch beliebig erweiterbar. Obwohl das Modell die Realität nur in eingeschränkter Weise abbildet, bietet es eine Ausgangsbasis für Unternehmen ihre Multisourcingstrategien zu bewerten und zu verbessern. Dabei beinhaltet es einen theoretisch fundierten ökonomischen Ansatz, der eine praxisorientierte Weiterentwicklung der Entscheidungsunterstützung bei IT-Multisourcingentscheidungen ermöglicht.

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II.5 Multivendor Portfolio Strategies in Cloud Computing

| | |
|---------------|---|
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Cloud computing emerges as a powerful driver of the information technology industry and many companies are willing to exploit the advantages this development bears. However, services provided by the cloud are subject to default which can result in major economic damage for the client. Moreover, different cloud service providers may also bear a conjoint risk and may therefore not default independently. Hence, to implement effective cloud sourcing strategies, this paper postulates requirements for evaluating multivendor sourcing decisions to select cloud service providers, considering cost, cloud computing specific risk, and interdependencies. We develop an analytic model that meets these requirements and quantitatively expresses the specific cost and risk structure of cloud computing sourcing decisions. Our approach is based on Portfolio Theory with regard to the specifics of fungible cloud services by using exponential loss distributions and one-sided risk measures. Thereby, an evaluation and optimization of a client's cloud service provider portfolio is possible. To determine the value added we use a simulation for the evaluation of our approach.

Keywords: Cloud computing, IT portfolio management, service provider selection, decision model.

II.5.1 Introduction

The prevailing topic of cloud computing is supposed to reshape the information technology industry during the next years (Leavitt, 2009). Thereby, the economic and practical potential of this technology appears to be tremendous. Cloud computing providers like Amazon or Google are continuously extending their computing infrastructures, platforms, and services. The market-research company International Data Corporation expects expenditures on IT cloud services to 'account for 25 percent of annual IT expenditure growth by 2012 and nearly a third of the growth the following year' (Leavitt, 2009). Hence, cloud computing may have the potential to transform large parts of the IT industry (Armbrust et al., 2010). To retain control and thereby overcome adoption reluctance, an economic risk assessment of cloud services and a comparison of different providers are necessary (ENISA, 2009). This includes the evaluation of a provider's respective availability, recovery rate, and viability (Heiser and Nicolett, 2008). Lee et al. (2003) point out that service providers' system failure can result in major loss of productivity for clients. Therefore, the clients' businesses depend on the cloud service providers' wellbeing. The availability of cloud computing services is a major concern for companies. 'The interruption of data availability has the same effect as a system failure, because it significantly impedes all processes affected' (Martens and Teuteberg, 2011). For example, due to a power outage, datacenters of Amazon and Microsoft near Dublin were blacking out resulting in a default of both, the Amazon Elastic Compute Cloud (EC2) platform as well as the Microsoft Business Productivity Online Suite (Miller, 2011). The online storage service called 'The Linkup' shut down on August 8th, 2008 after losing access to 45% of customer data. Therefore 20,000 users had to be told that the respective services are no longer available (Brodkin, 2008). Unlike other IT (sourcing) projects, cloud services show a specific asymmetric risk structure with relatively low expected costs but very high economic damage in case of default. To reach an economic valuation of sourcing decisions for cloud sourcing strategies in accordance with general IT governance guidelines, a cloud specific risk assessment as well as the consideration of interdependencies and diversification effects is inevitable. However, Venters and Whitley (2012) state that still many organizations have a poor understanding of their costs, cannot evaluate the benefits, and only have limited ability to quantify the risks of cloud computing. Against this background we develop an analytical model to evaluate the ex ante allocation of shares to multiple cloud service providers, taking into account the service providers' costs and default risks. Since the economic attributes of cloud services can be very diverse, we chose to tailor our model towards a specific class of cloud services with basic attributes in order to guarantee comprehensible results, i.e. fungible cloud services, which can be independently allocated to different cloud service providers and for which a short-term provider switch is no effective solution to keep the business running. Examples for such cloud services are hosted desktops, hosted exchange and e-mail services, shared workspace systems, the provision of online storage and intra-company file sharing, as well as for hosted Anti-Spam/Anti-Virus solutions for e-mail security in the cloud. What these services have in common is that a provider's default may result in severe economic damage for the user, since the continuation of operations depends on the services' availability.

Based on existing literature, we postulate three requirements which we consider to be essential for an evaluation of cloud service provider portfolio composition. Then, we provide a brief survey of essential literature with regard to existing valuation methods and describe our research methodology. The

article's novelty is based upon a new approach to model the asymmetric risk structure of specific cloud services with the use of exponential loss distributions and a one-sided risk measure in analogy to technical failure rates to depict a reasonable image of reality. Thereby, we extend existing Portfolio Theory towards the specific characteristics of cloud services. We conclude with a valuation and optimization method for a cloud service provider portfolio. We present a practical example, evaluate our model using a Monte Carlo simulation, and illustrate real world implications of our work, before addressing the prospects and limitations of the model.

II.5.2 Research Objectives

Considering a profit-maximizing company, the economic benefits of a technology are in the spotlight of decision-making. Companies are challenged to allocate budget to the most promising combination of IT-services by using methodically rigor valuation methods to assess available IT services (Reyck et al., 2005). Despite this necessity, only 50% of all companies examined by the IT Governance Institute have a clearly defined approach for evaluating IT (IT Governance Institute, 2008). Considering the specifications of cloud computing sourcing investments, we postulate the following requirements.

R1: Cost integration: In general, cloud computing decisions induce costs to a client, e.g. service costs, agency, capital or implementation costs (Martens and Teuteberg, 2011). Thus, a valuation method has to integrate the occurring costs of cloud services.

R2: Consideration of the cloud computing specific risk structure: As mentioned above, providers of cloud computing services bear the risk of default resulting in a temporary service unavailability. The unavailability might be caused by different incidents like technical breakdown, operative errors or natural disasters. In case of default the client is unable to conduct its business processes for the duration of the unavailability of the service and hence has to bear profit setbacks. This one-sided risk structure needs to be adequately considered. In existing IT project/portfolio evaluation methods, risk is often interpreted as a two-sided deviation from a target variable, e.g. the expected costs, like in Fridgen and Müller (2009) and Zimmermann et al. (2008). However, a two-sided risk measure is incapable of depicting the one-sided risk structure of cloud computing services. Therefore, a valuation method has to consider this cloud computing specific risk structure. Requirement R2 is in the focus of this article to enable a cloud specific extension of Portfolio Theory.

R3: Consideration of risk interdependencies and diversification effects: If a client sources a cloud service to multiple providers, the default risks of the service providers are not independent of each other. On the one hand, risk is mitigated through the partitioning of the service provision; on the other hand it is possible that certain risks affect multiple service providers simultaneously. These conjoint risks, affecting for example a certain geographical region, technology, etc., appear in addition to a cloud service provider's specific risk. They occur very infrequent, but may cause high economic damage (Giesecke, 2003). Possible practical examples of cloud computing risk interdependencies are network breakdowns, e.g. by transection of deep-sea cables, large-area electric power breakdowns, or the unavailability of a basic supply service, which is accessed and indispensably required by a certain group of service providers (cascading risk transfer). Different cloud service providers which offer hosted desktops or hosted exchange- and e-mail services might rely on the same infrastructure provider, like

Amazon's Elastic Compute Cloud. Since many providers are recently locating their large datacenters in areas where power and cooling are cheap in order to maximize their economic profit from economies of scale (Armbrust et al., 2010), conjoint risks due to geographical proximity are becoming more and more likely. However, if a client obtains a desired cloud service from multiple service providers, whose risks are not perfectly positively correlated, the overall risk is lower than the total risks in case of perfect positive correlation due to diversification effects. For example, a client that uses hosted desktops from two or more cloud service providers keeps its core ability to work at least for a certain part of its employees, even if one provider defaults. This effect has to be considered by a valuation method.

As we will point out more detailed in the next section, to the best of our knowledge, there are no existing valuation methods for cloud computing portfolio management approaches considering all of the three mentioned requirements. To address this issue, our valuation model will answer the following two research questions, thus contributing to a better understanding and exploitation of the economic potential of cloud computing:

How can a cloud service provider portfolio be evaluated considering cost, interdependencies and the cloud computing specific asymmetric risk structure?

How can a client identify the optimal cloud computing portfolio allocation strategy?

II.5.3 Literature Overview

Many research articles address cloud computing business models and business-related issues of cloud computing, e.g. Pueschel et al. (2009) and Weinhardt et al. (2009). Companies willing to use cloud computing services need a comprehensive strategy to manage cloud services' cost, its specific risk structure as well as interdependencies. For this purpose, they use the support of decision models. Existing articles examine various aspects of sourcing decisions in general, and are based on several common theories applied in IS research, e.g. Social Exchange Theory (e.g. Kern and Willcocks, 2000), Transaction Cost Economics Theory (e.g. Aubert et al., 1996) or Agency Theory (e.g. Bahli and Rivard, 2003). Since in general sourcing decisions are similar to portfolio decisions on for example risky financial assets or IT projects, cf. Zimmermann et al. (2012), this contribution is based upon Portfolio Theory. In this vein, the 'critical target figures of a portfolio are its expected return and risk' as well as 'its interdependencies to all other investments included in a portfolio' (Zimmermann et al., 2012). Related articles in IS research using this theory are for example Wehrmann et al. (2006), and Zimmermann et al. (2008). They focus on IT outsourcing in general and do not adapt the theory according to the characteristics of cloud services. They use the variance as a two-sided risk measure to capture risk and picture interdependencies by the use of the Pearson's correlation coefficient. Thus, existing approaches based on Portfolio Theory consider both cost (R1) and project dependencies (R3), but fall short in capturing the cloud service specific risk structure (R2) and modeling it adequately. Other normative approaches like for example Martens et al. (2011) therefore provide a selection process for cloud computing providers with special focus on data sensitivity and risk attitude of the decision maker. The article contains an illustration of a respective decision process and does not provide a quantitative method-based decision support instrument. Existing contributions to the field

that focus on methodological decision support are for example Martens et al. (2012), who develop a Total Cost of Ownership (TCO) approach for cloud services and thoroughly describe different cloud computing pricing schemes as well as a high variety of cost factors of cloud computing. Fitó and Guitart Fernández (2012) introduce a semi-quantitative risk-management approach, which analyses and prioritizes cloud risks according to their impact on business objectives. Liang et al. (2012) provide decision models for cloud resource allocation focusing on cost and technical aspects like capacity, job turnaround time, latency and bandwidth. Martens and Teuteberg (2011) integrate risk in a decision model and model it by means of common security objectives. However, a cloud computing specific decision model with regard to all of the three mentioned requirements cannot be found. Hence, we analyzed general literature on IT outsourcing and decision theory in order to find approaches which might be suitable for a method transfer. The management of dependencies (R3) among various activities was already examined by Malone and Crowston (1990), who analyzed different types of dependencies and suitable management approaches. Interdependency effects are studied empirically by Mani et al. (2012), who focused on coordination between client and vendor. Bapna et al. (2010) developed an agenda for analytical and empirical research on multi-sourcing, focusing on a setting with multiple vendors who are competitors and co-workers at the same time. They found that due to interdependencies multi-sourcing is 'fundamentally different from single-sourcing' and that occurring cooperation and coordination efforts need to be analyzed carefully. Kundisch and Meier (2011) distinguished between different kinds of interdependencies and presented a structured identification process for resource interactions among IT projects and developed a mathematical decision model which accounts for the identified interdependencies. Probst and Buhl (2012) developed a model for sourcing decisions for IT services explicitly focusing on diversification effects. Lammers (2004) also considered IT service sourcing decision and use a risk-adjusted discount rate to model service provider risks. These approaches model risk by the means of symmetric distributions and therefore use two-sided risk measures. To the best of our knowledge a transfer of these approaches to the specifics of cloud computing is not possible, since risk shall be modeled as one-sided deviation from an expected availability rate to picture the facts of cloud computing more realistically. Martens et al. (2012) state that the 'evaluation and selection process of Cloud Computing Services is frequently conducted ad-hoc and lacks systematic methods to approach this topic'. For this reason, we develop a quantitative risk/cost based model for cloud computing investment decisions using a one-sided risk measure and considering exponentially distributed losses in case of default. Thereby, our work emphasizes specific characteristics of cloud computing, like easy accessibility and reconfiguration in terms of scalability. Thus, we are able to extend the IS literature based on Portfolio Theory with regard to specific risk modelling of cloud services and derive an economic model that delivers relevant insights supporting the design of cloud computing decision processes in today's businesses.

II.5.4 Research Methodology

In the context of this work we adopt a design science approach according to Hevner et al. (2004). Our approach to portfolio selection in cloud computing is designed as an artefact. Since it is a model that enables comparison to other approaches in this research area and it is a method that supports the process of portfolio selection in cloud computing, it is a valid artefact type (March and Smith 1995). We gave a brief overview of descriptive literature on cloud computing and pointed out the need of

quantitative decision support for cloud computing vendor selection. Since no adequate solutions exist in the extant knowledge base, the first phase (rigor phase) according to Hevner's DSR Approach (Hevner et al., 2004) is accomplished. For the construction of the artefact we relied on Portfolio Theory, as well as on Decision Theory and mathematical methods and related literature dealing with decision support for sourcing. To evaluate our approach to portfolio selection in cloud computing, we follow the methods proposed by Hevner et al. (2004) using a simulation and demonstrate that it will lead to better results than approaches applied in practice today. Thus, this paper provides a basis for the presentation of this approach to technology as well as management oriented readers. Researchers should feel encouraged to challenge the described limitations as well as to validate the proposed effects by empiricism. The findings derived subsequently should continuously improve the approach and therewith the decision support in today's businesses.

II.5.5 Multivendor Sourcing Decision Model

Despite traditional IT outsourcing and cloud computing provide similar basic functions and benefits (Leimeister et al., 2010), many limitations of traditional IT outsourcing do not apply to the concept of cloud computing (Talukder and Zimmerman, 2010). The providers of cloud services are subject to availability risk caused by individual or conjoint default. Both risks constitute the asymmetric risk structure of cloud services with relatively low expected costs but extremely high damage in case of default. In order to receive a specifically tailored model, we picture risk as technical failures, which are, in contrast to general IT outsourcing settings where defaults have a much broader variety of reasons, a very typical default reason of cloud services. Moreover, our model is continuous and considers fungible cloud services, which can be independently allocated to multiple service providers. This is not the case for other cloud services, or SaaS in general, where a service is delivered either by one specific supplier completely, or by multiple suppliers, each with precisely pre-defined scope (e.g., online storage is a fungible service, which can be independently allocated to multiple providers, whereas order entry as a Service is not). Due to these reasons, our model is first and foremost applicable to fungible and independent cloud services and not directly applicable to IT outsourcing settings or SaaS in general. Hence, our model cannot claim to be universally applicable, but intends to provide a realistic modeling approach of the specific risk structure of specific cloud services.

Setting and Assumptions

To conduct business, a client decides on deploying a specific service obtained through the cloud. As mentioned above, we focus on cloud services which are fungible, can be independently allocated to multiple service providers, and for which a short-term provider switch is no effective solution to keep the business running. We refrain from a technical investigation of cloud computing related problem solving. Instead, we examine the use of multiple cloud providers as a strategic or project management related means to deal with the problem of cloud computing service availability. Therefore, n multiple cloud service providers exist which render the desired service either completely or to some extent. The client has to decide ex ante on the respective share w_i of the service that will be obtained from provider i , with $\sum_{i=1}^n w_i = 1$. Considering a possible default of a service provider, clients are generally able to switch to an alternative provider, which in such cases might be a lengthy and complex migration project. However, even a fast provider switch cannot avoid unavailability of a service, since it takes

time until a client notices the default, gathers information about possible courses of action, chooses an alternative solution and switches to the respective provider. During this entire time span, economic damage accrues due to the interruption of business operations. Hence, we omit short term provider switches for our model and state the following assumption:

A1: The possibility of a short term change of the service provider is neglected for the considered period of time.

Referring to R1: Cost integration:

Each provider i offers a service to the client at certain costs c_i , whereas c_i being the costs for the provision of the complete service, i.e. $w_i = 1$. We consider the present value of all costs, e.g. initiation costs, negotiation cost, agency costs, coordination costs (Martens and Teuteberg, 2011), to be integrated in c_i .

Referring to R2: Consideration of the cloud computing specific risk structure:

The service offered by provider i is subject to default. This risk is modeled by the random variable $\tilde{\tau}_i$, which indicates the duration of unavailability of the service within the considered period. We infer that the longer the duration of unavailability, the higher the economic damage. Therefore, we state the following assumption:

A2: The economic damage \tilde{D}_i increases linearly with the duration of unavailability $\tilde{\tau}_i$ of a service, i.e. $\tilde{D}_i(\tilde{\tau}_i) = \tilde{\tau}_i \cdot d$, with $d > 0$ being the client-specific damage.

Since \tilde{D}_i is functionally dependent on the random variable $\tilde{\tau}_i$, \tilde{D}_i is also random. In practice, the economic damage may also stand in other than a linear relation to the duration of unavailability, e.g. convex, quadratic or exponential, relations. The model could easily be tailored to such other relations by adapting the factor d to be any desired function of $\tilde{\tau}_i$. We use assumption A2 as simplification which does not alter the model's findings. In case of unavailability of the service, providers are typically obliged to render compensatory payments specified by their SLAs. For example, if a client of Amazon's cloud service EC2 drops below the guaranteed duration of availability, the client 'is eligible to receive a service credit equal to 10% of their bill' (Amazon Web Services, 2008). Since the uncertain economic damage \tilde{D}_i on behalf of the client is unknown to and not influenceable by providers like Amazon, it is not appealing to them to grant a higher compensation. Related to the compensatory payment, the economic damage e.g. due to loss of customer data and thereby delayed business processes is likely to be much higher, which makes the risk of default almost completely born by the client. Venters and Whitley (2012) state that unlike regular outsourcing SLAs, cloud service SLAs 'are often weak and ineffectual' and 'currently poor vehicles for customers'. Durkee (2010) finds that 'in the cloud market space, meaningful SLAs are few and far between, and even when a vendor does have one, most of the time it is toothless'. Therefore, and for reasons of simplicity, we state the following assumption:

A3: Compensatory payments are neglected.

To model the distribution of the duration of unavailability $\tilde{\tau}_i$ we have to consider the fact that cloud providers do not have an incentive to publish empirical data for their services' unavailability times.

Thus, we follow an established method of modeling technical failure rates with an exponential distribution, with shorter durations of unavailability like e.g. due to power outages or server outages being more likely than longer ones like e.g. bankruptcy of a provider.

A4: The duration of unavailability \tilde{t}_i of a service is influenced by the provider-specific risk, modeled by an exponential distribution determined by the recovery rate $\lambda_i > 0$.

The recovery rate λ_i defines the capability of a cloud service provider to fix a service in case of default. Thereby, a high recovery rate refers to a broad expertise of a service provider to decrease the duration of unavailability.

Referring to R3: Consideration of risk interdependencies and diversification effects:

Besides the provider-specific risk, conjoint risks affect multiple cloud service providers i and j simultaneously. Following Duffie and Garleanu (2001) and Marshall and Olkin (1967), we model these conjoint risks according to the following assumption:

A5: Dependencies between the durations of unavailability of two services are pictured by the conjoint risk, modeled by an exponential distribution determined by the recovery rate $\lambda_{ij} > 0$. All dependencies are assumed to be linear.

The recovery rate λ_{ij} defines the existing external capability to fix a service in case of default, which is for example influenced by a certain region's electricity grid and respective support. Again, a high recovery rate refers to a broad expertise to decrease the duration of unavailability. The provider i 's duration of unavailability \tilde{t}_i can now be described by a bivariate exponential function $F(\tilde{t}_i)$ considering both the provider-specific risk as well as the conjoint risk. Since the service provider's statement of its duration of unavailability DU_i given by the respective SLA, e.g. 'we guarantee 99.5% availability', is the best information accessible, we state the following assumption:

A6: The statement of duration of unavailability DU_i equals the expected value of the bivariate exponential distribution $E(F(\tilde{t}_i))$.

As the expected value of the bivariate exponential distribution can be calculated according to (Giesecke, 2003) as

$$E(F(\tilde{t}_i)) = \frac{1}{\lambda_i + \lambda_{ij}},$$

we can state that

$$DU_i = E(F(\tilde{t}_i)) = \frac{1}{\lambda_i + \lambda_{ij}}.$$

Since a cloud service provider tries to avoid contract violations, the information DU_i given by the provider might not equal the true expected duration of unavailability, which might be derived from empirical values (Sripanidkulchai et al., 2010). The integration of this factor, as is, might therefore be a very cautious calculation. Empiricism could therefore come up with industry specific corrective factors, which could easily be integrated in the model.

Referring to all three listed requirements:

To picture the risk of unavailability of a service appropriately, we use the concept of lower partial moments (LPM), which measure one-sided deviations from a certain threshold, i.e. downside-risk. Therefore, the risk of unavailability of a provider is measured by the second order lower partial moment $LPM_2(0; \tilde{t}_i)$, with 0 being the damage threshold and \tilde{t}_i the decisive random variable. To evaluate a portfolio with respect to all requirements mentioned above, we compose an objective function as the client's decision criterion that integrates the portfolio's expected costs (denoted as μ_{PF}) and risks ($LPM_{2,PF}(0; \tilde{t}_i)$) weighted by the individual risk aversion of the decision maker, measured by the parameter γ . We state assumption A7:

A7: The client determines the risk-adjusted costs of a cloud computing portfolio PF using the following objective function: $\Phi(\mu_{PF}, LPM_{2,PF}(0; \tilde{t}_i)) = \mu_{PF} + \gamma \cdot LPM_{2,PF}(0; \tilde{t}_i)$. The client is risk-averse, i.e. $\gamma > 0$.

We assume a risk-averse decision maker, which means that the higher the unavailability risk of a service, the lower the client's willingness of choosing it. The exact determination of parameters of risk aversion is difficult and subject to further research. Similar objective functions are used by other authors within the IS discipline, e.g. Fridgen and Mueller (2009), Probst and Buhl (2012), Zimmermann et al. (2008).

Portfolio Selection of Cloud Computing Providers

The client's objective is to minimize the risk-adjusted costs of the portfolio, i.e. the value of the objective function. For this purpose, we derive the objective function's constituent parts for a cloud service provider portfolio μ_{PF} and $LPM_{2,PF}(0; \tilde{t}_i)$. The expected costs μ_i for provider i 's complete service are measured by the costs for the provision of the complete service c_i plus the expected damage $E(D(\tilde{t}_i))$, which consists of the expected duration of unavailability $E(F(\tilde{t}_i))$ multiplied by the client-specific damage rate d :

$$\mu_i = c_i + E(D(\tilde{t}_i)) = c_i + E(F(\tilde{t}_i)) \cdot d = c_i + \frac{1}{\lambda_i + \lambda_{ij}} \cdot d$$

The expected cost of a portfolio of cloud service providers μ_{PF} is the sum of the expected costs for all providers μ_i weighted with their respective shares w_i : $\mu_{PF} = \sum_{i=1}^n w_i \cdot \mu_i$

Furthermore, the unavailability risk of a portfolio of providers is measured by the $LPM_{2,PF}(0; \tilde{t}_i)$. Following Wojt (2009) and using the second order lower partial moment considering both the provider-specific risk as well as conjoint risk, we get:

$$LPM_{2,PF}(0; \tilde{t}_i) = \sum_{i=1}^n \sum_{j=1}^n w_i \cdot w_j \cdot CLPM_{1,ij}(0; \tilde{t}_i)$$

Thereby, $CLPM_{1,ij}(0; \tilde{t}_i)$ is the first order co-lower partial moment between the service providers, with

$$\text{CLPM}_{1,i,i}(0; \tilde{t}_i) = \text{LPM}_{2,i}(0; \tilde{t}_i)$$

and
$$\text{CLPM}_{1,i,j}(0; \tilde{t}_i) = \text{LPM}_{1,i}(0; \tilde{t}_i) \cdot \text{LPM}_{1,j}(0; \tilde{t}_i) \cdot \rho_{ij}.$$

ρ_{ij} pictures a correlation coefficient and therefore is a measure of the coherence between the respective risks of unavailability of the service providers, which is determined by the provider-specific risks as well as the conjoint risk. Following Marshall and Olkin (1967), this linear dependency can be pictured as

$$\rho_{ij} = \frac{\lambda_{ij}}{\lambda_i + \lambda_j + \lambda_{ij}}.$$

If the providers' durations of unavailability are independent of each other, in this case the correlation $\rho_{ij} = 0$. Furthermore, as $\lambda_i > 0$ and $\lambda_{ij} > 0$, we find that $\rho_{ij} \geq 0$. This implication of the model is reasonable, since a setting where the duration of unavailability of one service provider negatively affecting the duration of unavailability of another one is very unlikely. Given the correlation coefficient and the service providers' statements for the duration of unavailability from the SLAs, the relevant parameters λ_i , λ_j and λ_{ij} can be derived mathematically.

To provide a suitable evaluation method for cloud computing service providers in terms of our first research question, we combine expected costs and risk in the decision maker's objective function:

$$\phi(\mu_{PF}, \text{LPM}_{2,PF}(0; \tilde{t}_i)) = \sum_{i=1}^n w_i \cdot \mu_i + \gamma \cdot \sum_{i=1}^n \sum_{j=1}^n w_i \cdot w_j \cdot \text{CLPM}_{1,i,j}(0; \tilde{t}_i)$$

The decision maker can use this objective function to evaluate a possible allocation of services w_i with regard to the resulting risk-adjusted costs under consideration of the decision maker's specific risk aversion. However, it still has to be identified which combination of shares of the cloud service providers is best for the decision maker. To address this issue in terms of the second research question, we use the deduced evaluation method as a basis and formulate the problem as $\text{Min } \phi(\mu_{PF}, \text{LPM}_{2,PF}(0; \tilde{t}_i))$. Here we face a nonlinear optimization problem with a vector of decision variables $\vec{w} = (w_1, \dots, w_n)$ subject to two constraints: $\sum_{i=1}^n w_i = 1$ and $w_i \geq 0, \forall i \in N$. The analytic solution of such problems is possible but rather complex and would go beyond the scope of this contribution. However, to provide an analytical optimum in this paper, in the following, we concentrate on a setting with two service providers. This implicates a minimization of the risk-adjusted costs, resulting from the chosen optimal portfolio weights for $n = 2$ providers with $w_2 = 1 - w_1$. To fulfill the first order condition for optimality we set the first derivative with respect to w_1 equal to 0. By solving $\frac{\partial \phi(\mu_{PF}, \text{LPM}_{2,PF}(0; \tilde{t}_i))}{\partial w_1} = 0$ for w_1 we get a candidate for optimality \tilde{w}_1 . To fulfill the second order

condition for optimality, we examine the second derivative with respect to w_1 $\frac{\partial^2 \phi(\mu_{PF}, \text{LPM}_{2,PF}(0; \tilde{t}_i))}{\partial w_1^2} > 0$. For reasons of convenience, we do not depict the mathematical terms of the optimization. Considering all parameters in the previously defined domains, the second derivative is always positive and therefore the second order condition is always fulfilled. In case of optimization outcomes outside the interval $[0,1]$ we apply 0 at minimum and 1 at maximum. Hence, $w_1^* = \tilde{w}_1$ and $w_2^* = 1 - w_1^*$

represent the optimal shares. The decision maker's optimal portfolio allocation strategy is to choose the shares according to the computed w_1^* and w_2^* thus minimizing the risk-adjusted costs.

Example of two cloud computing providers

A company decides to obtain the service of hosted desktops and therewith realize advantages like easy access from different locations, provider support, less energy consumption, and no high investment costs. The company wants to split the provided desktops between two service providers SP1 and SP2. If SP1 provides all hosted desktops, the costs of the service are $c_1 = 13,000$ monetary units (MU), whereas the costs of full service provisioning of SP2 are $c_2 = 15,000$ MU, including initiation costs, adoption costs and other. The economic damage \tilde{D}_i increases linearly with the duration of unavailability \tilde{t}_i which is the time in which the affected employees cannot access their desktops. The client-specific damage rate is $d = 110,000$ MU. The company's parameter of risk-aversion is $\gamma = 4$. The recovery rates given in the providers' SLAs are 99.95% (SP1) and 99.96% (SP2), respectively. Since both service providers are located in the same geographical region and natural disasters and electric power breakdowns might have simultaneous impact on the availability of both providers, the correlation coefficient is assumed to be $\rho_{12} = 0.25$. Given this data, the provider-specific recovery rates $\lambda_1 = 1,100$ and $\lambda_2 = 1,600$ as well as the conjoint recovery rate $\lambda_{12} = 900$ can be derived mathematically. To compare the results of the optimization to more pragmatic approaches, we examine the respective risk-adjusted costs for each of the following allocation strategies.

- optimization: The optimal shares, identified by the method described above, are allocated to the respective providers.
- cost-based decision: The provider who charges less for the respective services is chosen to conduct the service entirely no matter what risk the service bears.
- risk-based decision: The provider with the higher availability is chosen to conduct the service entirely no matter what price the provider charges.
- equal shares: Each service provider conducts the same fraction of the service.

To picture the calculation outcomes: according to allocation strategy 1 (optimization), the portfolio composition with optimal shares $w_1^* = 0.42$ and $w_2^* = 0.58$ leads to risk-adjusted costs of 20,127. Allocation strategy 2 (cost-based decision) recommends a selection of provider SP1, as the costs are lower than the costs of SP2, which implies risk-adjusted costs of 25,155. Allocation strategy 3 (risk-based decision) recommends a selection of provider SP2, as its risk (reflected by the LPM) is lower than the costs of SP1, which implies risk-adjusted costs of 22,788. Allocation strategy 4 (equal shares) leads to risk-adjusted costs of 20,220. Hence, the optimization outcome of the model presented above delivers the best results in this example. We use a Monte Carlo simulation to verify these results.

II.5.6 Model Evaluation based on a Monte Carlo Simulation

According to Hevner et al.'s (2004) design science approach, we provide an analytical optimization and simulation as legitimate means to evaluate a model. Since it is almost impossible to acquire real world

data to survey the value added of our allocation approach empirically, we derive realistic results via the simulation of scenarios. Each scenario was created by a variation of the basic parameters cost, recovery rates, and damage. To picture the availability of 99.95%, which is frequently given in cloud provider's SLAs we set the sum of the conjoint and provider-specific recovery rates equal to 2,000.

Table 1. Monte Carlo input data

| parameter | range | distribution |
|---|---|--------------|
| cost (c_i) | 0 – 20,000 (+/- 20% for different providers) | equal |
| conjoint recovery rate (λ_{ij}) | 0 – 2,000 | equal |
| provider-specific recovery rate (λ_i) | 2,000 - λ_{ij} (+/- 100% for different providers) | equal |
| client-specific damage rate (d) | 0 – 200,000 | equal |

We generated 50,000 different project settings and derive the following results: The allocation of cloud services according the optimization outcome dominates all of the three other allocation strategies, especially the magnitude of the improvement obtained through optimization is considerable. Compared to the cost-based decision, the optimization leads to an average improvement of 13.56% relating the respective risk-adjusted costs. Compared to the allocation decision of equal shares, the optimal allocation leads to an average improvement of 10.28%. Compared to the risk-based decision, the optimized allocation saves an average of 6.92%. By varying the parameter of risk aversion γ by steps of 25% in both directions, we performed an additional sensitivity analysis.

Table 2. Monte Carlo results: average improvement through optimization

| parameter of risk aversion γ | $\gamma = 2$ | $\gamma = 3$ | $\gamma = 4$ | $\gamma = 5$ | $\gamma = 6$ |
|-------------------------------------|--------------|--------------|--------------|--------------|--------------|
| optimization vs. cost-based | 9.93% | 11.42% | 13.56% | 15.61% | 17.80% |
| optimization vs. risk-based | 5.75% | 6.23% | 6.92% | 7.42% | 7.90% |
| optimization vs. equal shares | 9.66% | 10.06% | 10.28% | 10.47% | 11.31% |

These results have been statistically tested with the Mann–Whitney–Wilcoxon test and are highly significant, i.e. all p-values $\ll 0.01$. Hence, we can state that our findings hold irrespective of the value of γ . Therefore the application of our model features a significant potential to reduce risk-adjusted costs and enables companies to fully reap the benefits this technology bears.

II.5.7 Practical Implications, Limitations and Outlook

In this paper, we derive an analytical model to extend existing Portfolio Theory to quantitatively evaluate a client's cloud computing portfolio composition with regard to three requirements. Altogether, the following practical implications can be derived:

- The characteristics of cloud computing require an economic valuation approach with regard to costs, the specific risk structure and risk interdependencies.
- The model developed in this paper fulfills all of these requirements and provides decision support to evaluate cloud computing strategies as well as to determine the optimal provider selection.
- The allocation of cloud services according the model's optimization outcome delivers better results than approaches applied in practice today.

Considering the limitations of this approach, despite the underlying assumptions, one has to mention, that the model pictures ex ante decisions only. The development of an integrated model considering the existing cloud computing portfolio as well as the decision on additional services obtained through the cloud might be of great significance to practitioners as well as to researchers and is subject to further research. Furthermore, the relation between the announced duration of unavailability of a cloud computing provider, e.g. derived by SLAs, and its actual duration of unavailability, should be further examined. We focus on cloud computing services, which are very likely to be infinitely divisible and deliver constant merits no matter which service provider is chosen. The further examination of such services of which some real world examples are given above, along with the examination of other services, as well as the extension of the model to consider more than two providers analytically is subject to further research. Future empirical research has to further verify the validity of our hypothesis and go beyond the simulation based evaluation, to show that the developed model produces better results than approaches applied in practice today.

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III Optimization of Estimation Accuracy in Software Development Projects

According to the company's objective to create value, a viable ITPM has to assess the question of how much effort shall be put into the estimation of an IT project economically. Therefore, chapter III comprises one paper addressing the 'Optimization of Estimation Accuracy in Software Development Projects' (article A6).

III.1 Optimization of Estimation Accuracy in Software Development Projects

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The realized project value of many software development projects deviates significantly from ex ante estimates, which may lead to a misallocation of resources. This discrepancy is financially harmful for businesses dealing with IT projects in an increasingly competitive environment. Therefore, estimation accuracy and how to improve it is in the spotlight of many publications in the field of business information systems engineering (BISE). Oftentimes the tenor is that estimation accuracy is closely linked to the success of software development projects. So far, research has focused solely on the definition of estimation accuracy, on how accurate different estimation techniques and models are, and on how to improve accuracy. However, despite of a certain technique or sheer improvement, an optimal degree of estimation accuracy can be identified, since besides the possible positive effect on the project's success, the estimation creates cost itself. In the following, we derive a sound economic model which enables companies to determine a project's optimal estimation effort, taking into account cost and impact of estimation accuracy on the project. Therewith, we take a first step towards decision support for optimally allocating resources to the effort estimation of software development projects.

Keywords: Estimation effort; Accuracy of estimates; Software development projects; Risk/cost valuation; Optimization; Analytic model; Decision support;

III.1.1 Introduction

The success story of information technology (IT) within the world's economy leads to an increasing number of software-supported processes within many companies. Therefore, more and more software development projects take significant and rising shares of companies' budgets. Furthermore, effects like increased competition as well as scarce budget force firms to deal with cost cutting, which is necessary to stay in business. To be able to survive and prosper in an increasingly challenging environment, management is obliged to focus on the value-added when assessing investment decisions. The company's aim should be the realization of a value contribution of every investment, e.g. IT projects. Thus, if managed and implemented correctly, IT projects, and therefore software development projects, increase a company's value.

In today's project evaluation processes, usually a business case is calculated to decide whether to conduct a certain project or not. This goes in line with an initial (ex ante) estimate of the project's value. In many cases this value differs significantly from the realized (ex post) project value. Oftentimes this happens even unrecognized, since means to measure this deviation are missing and a process for evaluation is not implemented. Without a viable performance measurement, project management and controlling is impossible and the potential of value creation is not fully exploited. This is not in line with the company's aim to maximize value by managing IT projects optimally.

The more effort in terms of money is put into the estimation of the project value, a higher accuracy can be expected, i.e. in general the actual value is closer to the estimated one. Increasing estimation accuracy presumably leads to a decreasing project's risk, in terms of deviation from the estimated value. This risk reduction bears the chance of better resource allocation. However, one has to consider that there are various components of a project's risk which are not affected by estimation accuracy (Mantegna and Stanley 2000). These are for example general project risks like technical breakdowns, employee turnover, lack of communication in project teams, and many more which cannot be influenced even in the case of a perfect estimation. Only the estimation specific component is affected by estimation accuracy. Still solid information gathered through a precise estimation reduces the risk of wrong decision making.

Besides the positive effect on a project's risk, an estimation causes costs. Therefore, it is not worthwhile to increase the estimation accuracy arbitrarily. For example a complete planning of every conceivable scenario, even the very unlikely ones, might be a waste of effort. To support management of IT projects, this paper focuses on the money which is spent on the estimation of software development projects and on the risk reduction this estimation bears. A high accuracy, which seems desirable at first sight, is worthwhile only if the benefits of a higher accuracy are not outweighed by the effort which is put into the estimation. Therefore, an optimal estimation effort regarding cost and benefits of the estimation shall be identified. This paper is a first step towards a first structuration of the research area dealing with the optimization of estimation accuracy in software development projects. Therefore, it provides an initial economic modeling of the problem which should serve as a basis for empirical testing and evaluation.

Following a brief description of our research methodology in chapter 2, chapter 3 gives an overview of essential literature and points out the research question. Chapter 4 provides the general setting as well

as notations and assumptions of the approach. Based on that, a sound and rigor economic model is derived. In chapter 5 possible restrictions and practical implications of the approach are addressed and starting points for future research are identified.

III.1.2 Research Methodology

According to Meredith et al. (1989), who provide a research framework for quantitative modeling which is applicable to our approach, research activities should fit into a research cycle entailing three stages. The first stage consists of the systematic *description* of new or not yet observed circumstances, or deepens the insights of existing research. For this article, chapter three gives a brief overview of related literature from which we derive the research gap which our approach is trying to narrow. Based on the first stage, the second stage of the research cycle contains the *explanation* of the context in terms of reactions and relationships, as well as the derivation of normative approaches. To the best of the author's knowledge, a respective approach meeting the targets stated above does not yet exist and, due to the lack of data, observational real world investigations in this context seem difficult. An empirical analysis would need data of multiple comparable projects with different levels of estimation accuracy before and after the completion of the projects and therefore requires plenty of time to derive statements about the optimal estimation effort. This paper therefore aims at the identification of new relationships to provide a first scientific explanation of the problem at hand, which can provide a basis for a profound analysis and problem solving in future contributions. Therefore, a formal deductive model addressing the research question is developed. According to Meredith et al. (1989) this is a suitable method to conduct research within this stage of the cycle. The third stage of the research cycle consists of the *testing* of the described setting. The deductively derived relations of such models require a profound examination to what extent they are able to predict the phenomena explained. The focus here is not to provide a model which is directly applicable in practice as a single means of decision support, it rather enhances existing decision processes by a quantitative aspect and supports the deduction of new, empirically testable hypotheses. The findings derived subsequently should continuously improve the approach and therewith the decision support in today's businesses. This article provides a model and therewith a basis for empirical testing. However a profound empirical evaluation of the approach goes beyond the scope of this paper and is subject to further research.

III.1.3 Literature Overview

To narrow the topic we give a brief overview on relevant literature in the field of software cost estimation approaches, the process of cost estimation and point out similarities, and differences of related approaches. Therewith, we are able to identify the research gap which we are trying to narrow by answering the research question stated at the end of this chapter.

According to Jørgensen (2007) there is no uniform definition for the term „effort estimate“, which can for example refer to planned, budgeted or most likely effort. They state however, a „reasonable precise interpretation of the term ‘effort estimate’ is an obvious prerequisite for meaningful measures of estimation accuracy“ (Jørgensen 2007, p. 17). Therefore, we stipulate our understanding of the term ‘estimation’ and ‘estimation accuracy’: In the following, we refer to the planned project value, as present value of a project's expected cash flows, when talking of estimates. Concerning the accuracy of

estimates we refer to the deviation from planned to actual project value. In this context we pursue a quantitative and monetary interpretation of the term 'value'.

The accuracy of estimates is not always solely dependent on the process of the estimation as such (Jørgensen 2004a). Other factors might also influence estimation accuracy, like for example the level of estimation complexity, the estimators' or project members' skills, quality and availability of information, or whether cost-controls are implemented sufficiently within the organization or not (Jørgensen 2004a; Grimstad and Jørgensen 2006). During the course of the project, clients have also an impact on the estimation outcomes like for example due to changed and new requirements (Grimstad et al. 2005).

Overall in software development, estimation of costs, effort, or value, has been and remains very important (Benala et al. 2012; Boehm et al. 2000; Jørgensen and Shepperd 2007). Specifically, research on different estimation techniques and their application has been of interest for a number of years already. Many parametric models exist, like for example the Constructive Cost Model (CoCoMo) developed by Boehm (1981), the SEER-SEM (Software Evaluation and Estimation of Resources - Software Estimating Model) developed by Galorath (2006), or the SLIM (Software Lifecycle Management) developed by Putnam (1978). Models considering the size of a software development project are the Function Points Analysis or the Lines of Code approach developed by Albrecht (1983). Shepperd and Schofield (1997) presented a method using analogy to estimate a project's cost. According to Jørgensen and Shepperd (2007) expert judgment models, like the Delphi method developed by the RAND-Corporation (Dalkey and Helmer 1963) or work breakdown (Project Management Institute 2008) are increasingly used to estimate software development effort. Furthermore machine learning models, like neural networks (Venkatachalam 1993) or the fuzzy method (Attarzadeh and Ow 2010) are also becoming more common. Estimation techniques like CART (Classification and Regression Trees), Bayesian and Simulation are rarely used. However, as Jørgensen and Shepperd (2007) state, the diversity of the different software cost estimation approaches is fairly high and still increasing. But still the most accurate planning is worthless, if risks are neglected or mitigated only disproportionately. Therefore, a greater focus has been placed on the uncertainty of effort estimates (Jørgensen and Shepperd 2007).

As stated above, most of the mentioned articles focus on the identification of ways and means to estimate more accurately. However, on the one hand, there has been very little quantitative research concerning how much effort should be put into the estimation as such. On the other hand, literature on how to improve estimation accuracy by comparing which estimation model leads to better results is rather extensive (Jørgensen and Grimstad 2010). Walter and Spitta (2004) categorize and assess approaches for the ex-ante evaluation of IT projects. They find that there is not one single method that is suitable for evaluating a project entirely. A combination of methods might be favorable but is not easily operable. Rammage et al. (2010) provide a roadmap for a software cost estimation process for improved estimation accuracy combining different estimation techniques. They state that documentation of the estimation and re-estimation on a regular basis as well as due to changes in the project environment are important factors influencing the success of a project. Furthermore, they point out that estimation causes a certain effort, however they do not account for a quantification thereof and respective integration into the project decision. In contrary to the contributions listed above, this

paper analyzes how the effort that is put into the estimation (i.e. the estimation cost) influences the decision on a certain project. In a related approach concerning the analytic procedure, Bartmann (2012) examines the trade-off between software development documentation effort and respective returns. However, the empirical evaluation of the estimation effort and therewith the derivation of best practices turned out to be rather difficult. Jørgensen (2004a) states, that estimation accuracy is influenced by a great variety of factors which prohibit an empirical derivation of general laws in this context. Furthermore the problem is that on the one hand data is not easily accessible. To derive rigor results large samples of comparable projects are necessary. On the other hand the derivation of best practices especially concerning an optimal strategy is almost impossible, since data allows for ex post evaluations only. As a first step to bridge this gap, a value-oriented and quantitative decision support by means of a formal decision criterion is needed.

Based on the assumptions stated below, this paper presents a model to determine the optimal estimation effort, measured in monetary units. To the best of the authors' knowledge, there exists no similar research addressing this topic yet. Therefore, this paper shall be seen as a first attempt to approach the following research question:

What is the optimal estimation effort for a software development project?

III.1.4 Model

In the following, we derive the setting and assumptions to be able to analyze a software development project's optimal estimation effort by means of a formal deductive model, taking into account cost and impact of the estimation accuracy on the project.

Setting

To evaluate a software development project's value, we consider costs and benefits of a certain project. In this context costs refer to the cash outflows a certain project causes, benefits to savings or cash inflows, respectively. Usually future cash flows are not deterministic, which is why a certain deviation of the actual value compared to the estimated value has to be considered. In the following this deviation is referred to as a project's risk. This implies the estimation of the respective values for a project's costs, benefits, and inherent risk. The more precise these parameters are determined the more time and therewith money is consumed by the estimation. Since estimates attend to future cash flows, uncertainty, in terms of a deviation of the actual value from the estimated value, has to be taken into account.

In view of estimation accuracy, both underestimation and overestimation of a project's value are unfavorable. In the first case, too few money is budgeted and fewer resources are scheduled than actually used. This excess consumption might lead to troubles with other projects competing for the same resources. In the second case, more money is budgeted and more resources are scheduled than actually used. This is unfortunate, because the additional budget or personnel could be used at a higher rate of return within other (IT) projects.

Therefore, an under- as well as an overestimation of a project's value bears the danger of resource misallocation and therefore may cause cost of reallocation. However, an increased estimation accuracy

supports project management to allocate resources more accurately and therefore might reduce the cost of reallocation.

Assumptions

A decision maker is considering a software development project. Prior to the implementation an estimation shall be conducted. The estimation aims at predicting a project's net present value (NPV).

A1: The NPV of a project is represented by a normally distributed random variable $NPV \sim N(\mu; \sigma)$, with μ denoting the expected value of the NPV, and σ denoting its standard deviation as a measure of risk. The decision maker is risk-averse.

To integrate the risk aversion into our model, we use the parameter α as a linear transformation of the Arrow-Pratt characterization of absolute risk aversion (Arrow 1971). Since we consider risk aversion only, $\alpha > 0$. The higher the value of α , the more risk-averse is the decision maker. A risk-averse decision maker favors the utility of a risk-free net present value over a risky net present value with identical expected value. To determine the value of α , a company can draw on a market's utility function (competitors etc.) and thereof derive α (Kasanen and Trigeorgis 1994). Similar formal approaches and assumptions for risk adjusted economic value analysis have been derived by Longley-Cook (1998) and have been applied in the context of IT portfolios numerous times, for example in Bardhan et al. (2004) Fridgen and Mueller (2009; 2011), Fogelström et al. (2010), Hanink (1985), and Zimmermann et al. (2008).

The decision maker tries to influence a project's risk σ by choosing a certain value for the estimation effort E , measured in monetary units. Therefore, the estimation effort $E > 0$ is considered to be the decision variable.

A2: The higher the estimation effort E the more precise is the estimation outcome and the lower is the deviation of a project's total net present value from the estimated one.

Therefore, the standard deviation is a function of the estimation effort: $\sigma(E)$. As stated above, this deviation from the original estimate is measured in monetary units, since it causes expenses in terms of cost of reallocation. To determine a project's optimal estimation effort, a decision criterion is needed. Therefore, we compose the following objective function.

A3: The decision maximizes a project's total value, which follows the structure $\Phi(\sigma(E)) = \mu - E - \alpha(\sigma(E))^2$.

The decision maker maximizes the entire project's risk adjusted net present value, which consist of the project's expected net present value μ , the estimation effort E , the parameter of risk aversion α , and the standard deviation as a function of E : $\sigma(E)$ as the measure of risk. The risk adjusted net present value can be interpreted as the certainty equivalent of the project's NPV for normally distributed random variables and an exponential utility function and thus as an amount of money. This approach is in line with the Bernoulli principle and an established method of decision theory (Bernoulli 1954; Bernoulli 1738; Markowitz 1959; von Neumann and Morgenstern 1947).

In the following, we examine the functional relationship between the estimation effort E and a project's risk $\sigma(E)$. The project's risk and therefore the costs of reallocation without any effort put into the estimation are depicted by σ_{max} , because the lower the effort put into the estimation the higher

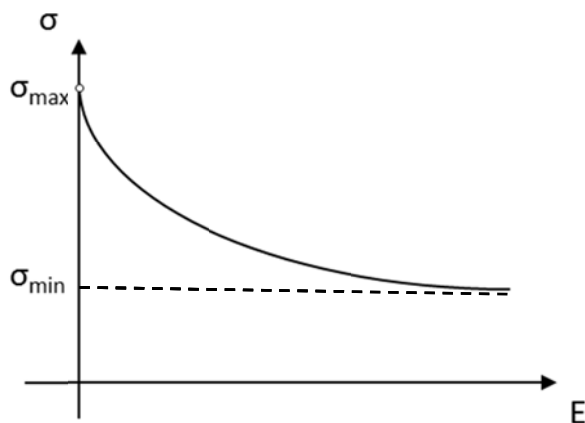
the deviation of the actual project value from the estimated value. Since without estimating σ_{max} is unknown, the function is defined for $E > 0$, only. There is a residual risk σ_{min} which is not influenceable by estimation. This risk is the quantitative graspable deviation of the expected net present value of a project due to external as well as internal influences, like for example economic development or mechanical malfunctions, respectively. Therefore, the risk component which is influenceable by estimation accuracy ranges between σ_{max} and σ_{min} .

To be more precise about the relationship between the estimation effort and the standard deviation of the projects net present value, we postulate the following requirements which shall be met by the function $\sigma(E)$:

- R1) A monotonically decreasing shape, since the higher the estimation accuracy the lower the associated standard deviation of a project's net present value.
- R2) Strict convexity, since we expect that increasing estimation accuracy leads to diminishing marginal benefits, i.e. a decreasing risk reduction.
- R3) Asymptotical approach to σ_{min} , since a rising estimation effort reduces risk but is not able to eliminate it totally. As mentioned above, σ_{min} pictures the risk which cannot be eliminated by higher estimation accuracy.

Following all four requirements the function exemplarily can be pictured as follows:

Fig. 1 Functional Relationship between Estimation Effort and Risk



To derive an optimum of the decision maker's objective function $\Phi(\sigma(E))$, we want to show that for all possible functions of $\sigma(E)$, which fulfill all of the requirements stated above, the objective function is concave and has a maximum. Therefore, we build the general derivatives:

$$\begin{aligned}\Phi(\sigma(E)) &= \mu - E - \alpha \cdot \sigma(E)^2 \\ \Phi'(\sigma(E)) &= -1 - 2 \cdot \alpha \cdot \sigma(E) \cdot \sigma'(E) \\ \Phi''(\sigma(E)) &= -2 \cdot \alpha \cdot (\sigma'(E)^2 + \sigma(E) \cdot \sigma''(E)) \stackrel{!}{<} 0\end{aligned}$$

To determine the functions slope and pole, we want to show that function is strictly concave and has a possible solution in the respective domain. Therefore we examine the second derivative $\Phi''(\sigma(E))$.

Since $\alpha > 0$, because we consider a risk-averse decision maker;

and $\sigma'(E)^2 \geq 0$ because of the square;

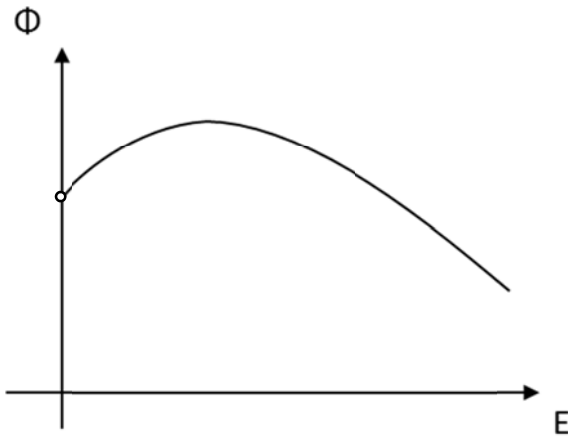
and $\sigma(E) > 0$, because σ ranges between $\sigma_{min} > 0$ and $\sigma_{max} > 0$;

and $\sigma''(E) > 0$, because the function is assumed to be strictly convex;

we conclude that $\Phi''(\sigma(E)) < 0$ and therefore the objective function is strictly concave.

To show that the objective function has a global maximum we need to examine if there exists an $\hat{E} > 0$ with $\Phi'(\sigma(\hat{E})) = 0$. Since $\Phi'(\sigma(E))$ is continuous for $E > 0$ and $\lim_{E \rightarrow \infty} \Phi'(\sigma(E)) = -1$, $\lim_{E \rightarrow 0} \Phi'(\sigma(E))$ has to be positive. This is the case if $\sigma'(E) < -\frac{1}{2 \cdot \alpha \cdot \sigma_{max}}$. If this condition holds true, a candidate for optimality \hat{E} exists. If the condition does not hold true, $\Phi'(\sigma(E)) \leq 0$, i.e. the objective function is monotonic decreasing, which means that the minimum possible estimation effort $\hat{E} = \varepsilon$ is the candidate for optimality. In this case the highest project value would be achieved with minimum estimation effort. This means that for example a rule of thumb should be applied to determine the expected project value without any additional effort put into the estimation, since in this case estimating more precisely has no positive effect on the project. Since a negative estimation effort $\hat{E} \leq 0$ is not interpretable, in this case again the marginal solution $\hat{E} = \varepsilon$ is the candidate for optimality. To verify if a candidate for optimality \hat{E} or ε is a genuine global maximum E^* , the objective function has to be positive $\Phi(\sigma(\hat{E})) \geq 0$ or $\Phi(\sigma(\varepsilon)) \geq 0$. If this condition holds true, a genuine global maximum $\hat{E} = E^*$ or $\varepsilon = E^*$ exists. If not, the project would not be conducted since it consumes value. Then, although a negative project value results, the minimum possible estimation effort is $\hat{E} = \varepsilon = E^*$, since it generates the lowest loss. The following graph exemplarily shows the objective function in the respective domain:

Fig. 2 Functional Relationship between Estimation Effort and Project Value



This general model shows that an optimal estimation effort, which maximizes the project value $\Phi(\sigma(E^*))$, can be derived. However, no statement about the exact amount can be made yet.

As a first step towards the operationalization of this approach, we derive the optimal estimation effort analytically. Therefore, we assume an exemplary equation which fulfills all of the three requirements stated above to picture the relation between the estimation effort E and the standard deviation $\sigma(E)$:

$$\sigma(E) = (\sigma_{max} - \sigma_{min})e^{-\beta E} + \sigma_{min}$$

The function's slope might be adjusted by the parameter β : $\beta \in \mathbb{R}^+$, since varying slopes of the function might also be observable in practice. β is assumed to be constant and pictures the proportion at which estimation quality transfers to risk reduction. Since the value of β might be company or at least industry specific, it is pictured by a variable. The corresponding value of β for particular industries or companies respectively might be determined by empiricism. Plugging the exemplary function for $\sigma(E)$ into the objective function, the certainty equivalent of a project's NPV subject to the estimation effort is:

$$\Phi(E) = \mu - E - \alpha(\sigma(E))^2 = \mu - E - \alpha \cdot ((\sigma_{max} - \sigma_{min})e^{-\beta E} + \sigma_{min})^2$$

To determine the optimal estimation effort E^* , the first derivative of the objective function with respect to E is set equal to 0.

$$\Phi'(E) = 2\alpha\beta e^{-2\beta E} \cdot (\sigma_{max} - \sigma_{min}) \cdot (\sigma_{max} + \sigma_{min}(e^{\beta E} - 1)) - 1 \stackrel{!}{=} 0$$

The equation is solved and reveals one¹ candidate for optimality:

$$\hat{E} = \frac{1}{\beta} \left(\ln(\sigma_{max} - \sigma_{min}) + \ln \left(\alpha\beta\sigma_{min} + \sqrt{2\alpha\beta + \alpha^2\beta^2\sigma_{min}^2} \right) \right)$$

As shown above for the general setting, \hat{E} is a maximum of the objective function $\Phi(E)$. If a candidate for optimality leads to a negative total project value $\Phi(\hat{E}) < 0$ the project shall not be implemented, we therefore omit these solutions. Consequently, based on the assumptions and in the respective domain a maximum and therefore an optimal value for the estimation effort $E^* = \hat{E}$ can be derived.

To analyze the optimum, we examine the effect of each parameter on the estimation effort E . As \hat{E} shows, the spread of $(\sigma_{max} - \sigma_{min})$ has a positive influence on the estimation effort. This means, that the higher the potential risk reduction from σ_{max} to σ_{min} the more money is spent on estimation accuracy to reap the benefits of the decreasing risk. The absolute height of either parameter σ_{max} or σ_{min} (ceteris paribus) also has a positive impact on estimation effort, since the willingness to pay for a same absolute risk reduction is higher the higher the risk. The parameter of risk aversion α also has a positive impact on the estimation effort, since the more risk averse a decision maker, the more impact has a potential risk reduction. Therefore, more money is spent on estimation accuracy to decrease the risk. Also the parameter β 's influence on the estimation effort is positive. β adjusts the slope of the function $\sigma(E)$ and pictures the proportion at which estimation accuracy transfers into risk reduction. Therefore, a higher value of β leads to a higher risk reduction and therefore increases the optimal estimation effort.

¹In the respective domain, a second candidate for optimality does not exist since the square root is always greater than the first part of the equation and a natural logarithm of a negative number has no solution.

The analysis of the parameters influencing the optimum does not show any irregularities and allows for a reasonable economic interpretation of the formal context of the model. To analyze the periphery of the optimum, we examine the curvature of our general objective function. Therefore, we build its third derivative:

$$\Phi'''(\sigma(E)) = -2 \cdot \alpha \cdot (\sigma(E) \cdot \sigma'''(E) + \sigma''(E) \cdot (\sigma'(E) + 2))$$

This reveals that no precise statement about the behavior of the general function $\Phi(\sigma(E))$ can be made, since the curvature of the objective function is dependent on the function $\sigma(E)$ and its specific derivatives. In general, the precise amount of the optimal estimation effort shall be invested to maximize the project's value. Nevertheless, to picture misconduct, we examine what happens if the investment exceeds or deceeds this amount. For the general formula a prediction whether a hesitant or decisive investment in estimation accuracy leads to less unfavorable results is not possible and therefore a profound analysis of the respective setting is necessary. To do so, we use our exemplary equation for $\sigma(E)$ and build the third derivative:

$$\Phi'''(E) = 2\alpha\beta^3 e^{-2\beta E} \cdot (\sigma_{max} - \sigma_{min}) \cdot (4\sigma_{max} + \sigma_{min}(e^{\beta E} - 4))$$

In this case $\Phi'''(E) > 0$, which means that the curvature increases with increasing estimation effort. Therefore, we can state, that with our exemplary function exceeding the optimal estimation effort leads to a higher decrease in project value than falling short of the optimal value. Consequently, a conservative investment in estimation accuracy would be less harmful than an overinvestment.

Results

As a first approach to the research question stated above: 'What is the optimal estimation effort for a software development project?', the model supports the decision maker in assessing the optimal estimation effort of a software development project in monetary units, based on the respective assumptions. This could facilitate a more efficient resource allocation within the company and might exploit the potential of added value. Therefore, companies might be able to allocate their budget at a higher rate of return which in turn leads to a competitive advantage over rivals. Combined with existing research on improving estimation accuracy, by picking the most effective approach therefor, the better results in terms of economic value creation might be realized. Hence, this approach broadens the potential of existing research to provide a basis for decision support according to economic objectives of practitioners.

III.1.5 Theoretical and practical contribution, Limitations and Outlook

Today, companies increasingly recognize the relevance of IT project management in general as well as in the context of estimation accuracy. Although it bears cost reduction potential, still little research exists in the field of identifying an optimal degree of estimation accuracy and its effects on an IT project. This paper provides a quantitative model as a basis for empirical evaluation to be able to help companies to improve their value estimation strategies. The vision of a value oriented quantitative determination of the optimal estimation accuracy concerning risk and return requires methodically

rigorous models that deliver initial reasonable results, although they might not be suitable to be applied in practice without adjustments.

The model also is subject to some limitations. For reasons of simplicity the approach considers the *NPV* of a project as normally distributed random variable. This is a reasonable assumption since the *NPV* could deviate in either direction at the same probability, however other distributions might also be justifiable. The integration of other distributions into the model might therefore provide a more eclectic picture of reality and might be subject to further research. The examination and assessment of the parameter β might also be the substance of upcoming publications. Furthermore, future research might extend the approach to consider multiple software development projects simultaneously as well as subsequently. A setting of a concurrent project portfolio, as well as a setting including follow-up projects could be analyzed. Considering the latter, a long-term view could be beneficial, as Jørgensen (2004b) states that previous estimation accuracy influences the decision on follow-up projects.

Although the model pictures reality in a slightly constrained way, it provides a basis for firms to enhance their value estimation strategies by a quantitative aspect. It enriches existing decision processes while supporting the deduction of empirically testable hypotheses. Moreover, it is a theoretically sound economical approach which allows for further development and delivers insights in the process of value estimation. This might be of great significance to practitioners as well as to IS researchers, who should feel encouraged to empirically drill on the limitations as well as to validate the proposed effects by empiricism.

III.1.6 References

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IV Conclusion and Future Prospects

Since IT evolved to be one major drivers for the world's economy, companies are trying to exploit the value creation potential this development bears. Therefore, an integrated ITPM should economically assess sourcing decisions for IT projects and portfolios as well as estimation accuracy of software development projects. The previous chapters II and III of this dissertation provide an analysis of these research areas. Chapter IV now gives a brief overview of the findings derived from the articles A1 – A6 in paragraph IV.1 and provides future prospects of research in paragraph IV.2.

IV.1 Conclusion

Considering sourcing decisions as one aspect of a value oriented ITPM, articles A1 - A5 provide the following outcomes: In response to the question which outsourcing degree a client should chose to minimize the risk adjusted cost of a single project (RQ 1.1), article A1 provides a quantitative model to determine an optimal outsourcing degree including price, transaction costs, risk and interdependencies of the outsourcing contract for a single project as well as the respective outsourcing degrees for a project portfolio (RQ 1.2). This model identifies an outsourcing strategy which minimizes the total project or portfolio cost, based on simplifying assumptions. It furthermore illustrates that a simultaneous optimization of portfolio composition and outsourcing degrees leads to more favorable results than a subsequent selection (RQ 1.3). Therefore, it might help companies to improve their portfolio selection processes and therewith their outsourcing strategies in the context of a value oriented ITPM.

As article A2 is based upon the model outlined in article A1, the major contribution are the findings derived from answering the question whether bargaining power influences the decision on the optimal outsourcing degree (RQ 2.2). The article states that for fixed price IT outsourcing decisions the client strives for a maximization of the overall benefit from IT outsourcing. Normally one would expect that a powerful outsourcing client closes outsourcing contracts which are more in his favor than in favor of the vendor by influencing the price of the outsourced service. Unintuitively, an optimal outsourcing degree can be identified independent from the client's bargaining power and therefore the pricing of the outsourced service. We conclude that bargaining power does not influence the decision on partial or complete outsourcing of a project. Therefore, A2 provides a more in-depth analysis of client-vendor relations in an outsourcing context to increase transparency concerning the value creation potential of IT.

Article A3 shifts the focus to optimally allocate multiple vendors to multiple subprojects. In response to the question concerning the optimal multivendor IT outsourcing strategy from a client's perspective (RQ 3.1), a method identifying the optimal vendor portfolio and considering monetary benefits, risk diversification as well as transaction costs, is derived. The examination of the effect of a risk assessment in this context (RQ 3.2) reveals that it makes good economic sense to include a risk evaluation into the multisourcing decision process even if it is subject to misestimation. Furthermore, the effect of neglecting risk is examined (RQ 3.3), which entails that overestimating risk causes less economic damage than underestimating it. Therefore, a cautious risk assessment is more beneficial. A3

therefore examines relations of multivendor IT outsourcing contracts and provides a guideline towards a more profitable multivendor IT outsourcing strategy according to the principles of a value oriented ITPM.

Article A4 implicitly answers the question which requirements a method for evaluating multisourcing decisions must fulfill and how difficulties with the application of the method could be overcome (RQ 4.1). Therefore, four requirements are identified, namely the assessment of risk, interdependencies and cash flows as well as the method's practical applicability. Then A4 summarizes the method developed to identify the optimal multivendor IT outsourcing strategy (RQ 3.1) as previously outlined in article A3. Furthermore, article A4 derives possible facilitating measures which address difficulties in the application of the method. Therefore, a simplified interval-based method is introduced which facilitates the estimation of the model's input parameters. Furthermore, a process is presented which enables a more practical determination of interdependencies. Moreover, a guideline is derived which allows for the identification of the risk-attitude of the decision maker. A4 therefore provides application support to practitioners and tries to narrow the gap between academia and practice in the context of multivendor IT outsourcing as an element of a value oriented ITPM.

Article A5 focuses the topic of cloud computing which evolved as a new form of traditional IT outsourcing. Answering the question of how a cloud service provider portfolio can be evaluated (RQ 5.1), A5 provides an analytical model that quantitatively expresses the specific cost and risk structure of cloud computing sourcing decisions using exponential default distributions and a one-sided risk measure. Thereby, a client's service provider portfolio can be evaluated and optimized while minimizing the total risk adjusted cost of the portfolio. The article contributes to a better understanding and exploitation of the economic potential of cloud computing. To support the models practical applicability (RQ 5.2) and support the client in identifying the optimal cloud computing allocation strategy (RQ 5.3), an example is given on how this model can be successfully applied by practitioners. A5 provides an evolution of existing evaluation methods for IT outsourcing towards a more flexible and dynamic assessment of outsourcing trends, like in this case cloud computing, to complement a value oriented ITPM.

Considering another aspect of IT project and portfolio management, which appeared to be relevant to practitioners participating in the research projects on IT outsourcing mentioned above, article A6 addresses the ex ante estimation of software development projects and therefore aims at identifying an optimal estimation effort for a software development project (RQ 6.1). As a first approach to this question, a model supporting the decision maker in assessing the optimal estimation effort of a software development project in monetary units is derived, based on simplifying assumptions. The model aims at facilitating a more efficient resource allocation within the company and therefore supports the creation of added value. With decisions based on - or supported by - this model, companies might be able to allocate their budget at a higher rate of return, which in turn leads to a competitive advantage over rivals. Hence, this approach extends the potential of existing research to provide a basis for decision support according to economic objectives of practitioners and allows for further formal-deductive development of the model as well as for empirical testing of the derived relations in the context of an integrated and value oriented ITPM.

To summarize the findings derived from chapter II ‘Sourcing Decisions in IT Project and Portfolio Management’ and III ‘Estimation Accuracy of Software Development Projects’, the quantitative models derived in the articles A1, A3, A5 and A6 together with their practical application outlined in article A2 and A4 enhance existing IT project and portfolio management by economic aspects. Besides the practical contribution, the models build a basis for further design-oriented research and allow for the deduction of new hypotheses and empirical testing thereof. The resulting connecting points for future research are outlined in the following chapter IV.2.

IV.2 Future Prospects

The performance of firms during the years of the economic and financial crisis showed again that IT, as a strategic factor, is able to improve a company’s competitive position through contributing to its value creation. Therefore, a viable IT portfolio management should provide methods for evaluating IT according to its value creation potential. In response to the challenging business environment IT outsourcing evolved as a measure to organize IT landscapes and applications more economically. In this context this dissertation outlines ways and means to evaluate outsourcing decisions of IT projects and portfolios as well as investments in estimation accuracy of software development projects according to the principles of economic value creation. The articles presented above (A1 – A6) furthermore involve multiple links for both, empirical as well as design oriented future work, which are outlined in the following.

To start out with article A1, it provides a basis for extensions of the fixed price IT outsourcing model considering default risks of outsourcing providers, returns of the service outsourced or other contract types than fixed price. Possible valuable enhancements might be the consideration of multiple project parts with different risk/cost structures, risk diversification effects in the price assessment as well as a evaluation of sourcing decisions over time. A possible extension of article A2 would be the investigation of the effect of bargaining power on outsourcing decisions in a portfolio context. Interesting results might be revealed by examining how bargaining power of either the client or the vendor(s) will influence the outsourcing decision of multiple projects. Article A3 raises a further question about the existence of an optimal intensity of risk assessment for IT outsourcing decisions. Furthermore, a consideration of qualitative factors in addition to the quantitative risk assessment might provide a more eclectic picture of reality. Again the model might benefit from an extension which considers a regular IT outsourcing project re-evaluation over time. A possible extension of article A4 would be a further refinement of the multivendor outsourcing model’s applicability and testing in practice. Article A5 opens up new research opportunities also considering an IT project re-evaluation over time and a portfolio view. Further cloud services as well as future innovative technologies could be also investigated and an empirical examination of the relations described by the model might be beneficial. Follow up research projects on article A6 might want to consider the integration of other probability distributions into the model of identifying the optimal estimation effort of a software development project. The empirical examination and assessment of the model’s relations might also be the substance of upcoming publications. Furthermore, future research might extend the estimation accuracy approach to consider multiple software development projects simultaneously as well as

subsequently. Here again, the integration of regular evaluation over time could be beneficial, since previous estimation outcomes might influence the decision on follow-up projects.

In general, each of the aforementioned articles (A1 – A6) captures a certain perspective on one or more of the research questions presented above and contribute to an integrated and value oriented ITPM. To generate a more holistic picture on the respective question, the corresponding assumptions should be relaxed and consequences on the model should be examined. By doing so, a deep understanding of the context and interrelationships of sourcing decisions and estimation accuracy as building blocks of an integrated IT portfolio management might be attained and management might be better prepared to cope with future challenges as outlined in the sequencing paragraph.

Since the 1960s the question about the provision of IT remained interesting, however, the focus is constantly shifting (Heinrich 1965; Lacity und Willcocks 1998). Whereas in former times the sourcing question merely focuses ‘make or buy’ decisions, nowadays increasingly ‘on demand’ or ‘pay per use’ models are pictured by outsourcing contracts. Also ‘asset free’ services, like for example services obtained through the cloud, are becoming more popular. This development shows, that up to now many different innovative business models constantly initiate new IT outsourcing processes. (Böhm et al. 2009) This evolution suggests the assumption that the situation will not change in near future. As the continually developing technological environment requires firms to adapt quickly to new circumstances, the question on how to evaluate different sourcing options and technologies will remain of great significance. To assure a higher level of decision support in this volatile atmosphere, future research should establish an integrated approach of IT project and portfolio management. Therefore, methods shall be developed and tested empirically to evaluate new technologies and sourcing opportunities considering the following requirements:

- Costs and benefits of an IT project have to be assessed monetarily
- The risk associated with a project’s cash flows has to be assessed monetarily
- The method should consider an IT project within the context of an IT project portfolio, therefore, interdependencies between different IT projects have to be assessed
- A qualitative assessment of the IT project’s characteristics has to accompany the quantitative evaluation
- The method should be applied regularly over the project’s lifespan to track the project value before, during and after a project
- The method has to be practically applicable requiring a low level of additional overhead

The main challenges for future research in this context are from this point of view the holistical consideration of a project’s cash flows, the repetitive re-evaluation of the IT project as well as the practical applicability of the methods. In the following, these three major issues are outlined more particularly.

The state of the art in assessing a project’s cash flows reveals that project costs are already evaluated in detail by several operable methods like the Constructive Cost Model of Boehm (1981). Corresponding methods concerning the management of an IT project’s benefits are still in the early stages of development (Flyvbjerg und Budzier 2011). The reason for this might be the fact, that in the

majority of cases, benefits of an IT project can just hardly be quantified or converted into monetary values. Moreover, benefits usually are not realized until the end of an IT project. Therefore, the quantification of benefits in practice is mostly conducted using qualitative methods. Quantitative methods are seldomly used and especially monetary procedures are scarcely applied. Future contributions therefore might work on the holistic assessment of an IT project's cash flows.

Considering the re-evaluation of an IT project over time, Beer et al. state that the entire lifecycle should be assessed. Therefore, three different phases during the course of the project should be taken into account. The IT project should be evaluated before the project starts (ex ante), during the course of the project (ex nunc) and after the project ends (ex post). Recent literature and the state of the art in practice reveal that there are plenty of approaches calculating a business case for an IT project and therefore addressing the ex ante evaluation. However, approaches focusing the ex nunc or ex post evaluation are scarce. Future contributions might therefore extend existing models or develop new approaches to consider an IT project's cash flows, risks, interdependencies quantitatively as well as qualitatively over time.

Last but not least, an important requirement for the derivation of new methods addressing an integrated ITPM is the practical applicability (Beer et al. 2013). The design oriented derivation of decision support methods should aim at closing the gap between 'research in ivory towers' and the application of the developed methods in practice. To succeed, an empirical testing of the method's underlying relations as well as the improvement of the method's applicability through feedback from empiricism is vital. Therefore, researchers and practitioners should work collaboratively to advance existing IT project and portfolio management methods to the next level. Herewith, the vision of an integrated and holistic ITPM becomes more tangible.

Information technology is considered to be the main driver of the global economy in the 21st century and future prospects still promise a rise in importance (Maizlish und Handler 2005). Against this background, it is the task of a viable IT project and portfolio management to support the value creation of IT (Zimmermann 2008). Therefore, this dissertation contains quantitative methods that evaluate the value contribution of IT projects and portfolios in the context of sourcing decisions and estimation accuracy. The articles presented in this dissertation are building blocks towards an integrated IT project and portfolio management. Therefore researchers should feel encouraged to drill on the respective assumptions and limitations and continue along the path to improve the value creation potential of IT.

IV.3 References

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